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AMERICAN SOCIETY
FOR
TESTING MATERIALS.

AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

PROCEEDINGS
OF THE
TENTH ANNUAL MEETING

Held at Atlantic City, New Jersey,
June 20, 21, 22, 1907.

VOLUME VII.

EDITED BY THE SECRETARY, UNDER THE DIRECTION OF
THE COMMITTEE ON PUBLICATIONS.

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SUMMARY OF THE PROCEEDINGS OF THE TENTH ANNUAL MEETING.

ATLANTIC CITY, N. J., JUNE 20–22, 1907.

THE TENTH ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS was held at the Hotel Chalfonte, Atlantic City, N. J., on June 20–22, 1907. The total attendance at the meeting, including guests, was over 270.

The following members were present or represented at the meeting: Ajax Metal Company, represented by G. H. Clamer; American Bridge Company, represented by A. P. Hume; American Foundrymen's Association, represented by Richard Moldenke; American Steel and Wire Company, represented by S. M. Rodgers; Barrett Manufacturing Company, represented by W. S. Babcock; Florus R. Baxter; H. C. Berry; Bethlehem Steel Company, represented by E. O'C. Acker, R. D. Chapman and J. S. Hegeman; H. S. Betts; William A. Bole; W. A. Bostwick; Booth, Garrett and Blair, represented by Robert Job; C. W. Boynton; H. DeH. Bright; W. H. Broadhurst; John G. Brown; Samuel A. Brown; William L. Brown; F. O. Bunnell; J. H. Burn; Jacob Cambier; Cambria Steel Company, represented by George E. Thackray; William Campbell; John A. Capp; Carnegie Steel Company, represented by W. A. Bostwick, M. M. Hench, and Wm. Whigham; F. D. Carney; Central Iron and Steel Company, represented by P. D. Cameron, Wm. C. Cuntz, R. H. Irons and R. D. Peace; G. H. Charls; Frank P. Cheesman; Alexander J. Christie; James Christie; Sumner R. Church; Charles S. Churchill; Frank O. Clements; McGarvey Cline; J. Allen Colby; Colorado Fuel and Iron Company, represented by J. A. Cambier; E. A. Condit, Jr.; T. L. Condron; Frederick Conlin; Edgar S. Cook; Wm. A. Cooper; Harry C. Crawford; Frank H. Crockard; Robert A. Cummings; W. C. Cushing; Allerton S. Cushman; George C. Davies; W. C. DeArmond; Cyril DeWyrall; L. C. Dilks; H. E. Diller; Joseph Dixon Crucible Company, represented by Malcolm Mc-

Naughton; D. E. Douty; W. C. DuComb, Jr.; Charles B. Dudley; P. H. Dudley; H. O. Duerr; W. O. Dunbar; E. H. Dyer; Edward F. Ely; *Engineering Record*, represented by J. M. Goodell; S. M. Evans; B. F. Fackenthal, Jr.; *The Iron Age*, represented by A. I. Findley; H. J. Force; C. N. Forrest; William Forsyth; H. W. Foster; James B. French; Froehling and Roberston, represented by Andrew Robertson; William B. Fuller; James H. Gibboney; Henry F. Gilg; G. M. Goodspeed; H. S. Goodwin; William F. M. Goss; Thomas Tarvin Gray; Russell S. Greenman; N. B. Gregg; Ed. D. Gregory; R. E. Griffith; Chester J. Hague; E. L. Hancock; Elwood Stokes Hand; Arthur B. Harrison; William K. Hatt; *Drugs, Oils and Paints*, represented by G. B. Heckel; George P. Hemstreet; Rudolph Hering; Martin Hokanson; R. W. How; James E. Howard; A. P. Hume; Richard L. Humphrey; William G. Humpton; Robert W. Hunt Company, represented by Robert W. Hunt; Illinois Steel Company, represented by P. E. Carhart; F. P. Ingalls; *Iron Trade Review*, represented by A. O. Backert; H. L. James; John M. Jeffers; Robert Job; Jones and Laughlin Steel Company, represented by J. J. Shuman; E. F. Kenney; Lewis H. Kenney; J. A. Kinkead; W. J. Klinger; Joseph B. Knapp; Morris Knowles; D. A. Kohr; Paul Kreuzpointner; H. A. LaChicotte; Lackawanna Steel Company, represented by George L. Waterhouse; Gaetano Lanza; R. W. Lesley; E. Sidney Lewis; George T. Lewis; A. D. Little; Lowe Brothers, represented by Henry C. Lowe; Lucas and Company, represented by F. E. Elliott; D. W. Lum; T. D. Lynch; E. T. McCleary; Ernest B. McCready; J. W. McGrady; Charles F. McKenna; D. W. McNaugher; Edgar Marburg; William Marshall; John A. Mathews; Richard K. Meade; Mansfield Merriman; Rudolph P. Miller; Charles M. Mills; Leon S. Moisseff; Richard Moldenke; A. W. Munsell; National Tube Company, represented by Frank N. Speller; E. D. Nelson; Tinius Olsen; Logan Waller Page; W. M. Parks; Pennsylvania Steel Company, represented by J. V. W. Reynders and F. D. Carney; R. S. Perry; J. M. Peters; J. Howard Pew; James Madison Porter; Stephen C. Potts; Charles E. Price; H. H. Quimby; *Railway and Engineering Review*, represented by Willard A. Smith; J. V. W. Reynders; Clifford Richardson; Walter Riddle; George N. Riley; C. D. Rinald; S. M. Rodgers;

John A. Roebling's Sons Company, represented by H. J. Horne; Joseph Royal; F. E. Schmitt, representing *The Engineering News;* Henry B. Seaman; W. T. Sears; Samuel J. Shaw, Jr.; Charles Shannon; Shelby Steel Tube Company, represented by F. N. Speller; John M. Sherrerd; The Sherwin-Williams Company, represented by E. C. Holton; Jessie J. Shuman; C. E. Skinner; H. E. Smith; J. P. Snow; Henry Souther; C. R. Spare; Standard Steel Works, represented by H. deH. Bright; F. M. Stapleton; J. T. Stephenson; A. A. Stevenson; H. N. Stokes; E. Platt Stratton; S. W. Stratton; Emil Swensson; Howard Taggart; Arthur N. Talbot; Henry P. Talbot; William Purves Taylor; A. R. Thomas; Gustave W. Thompson; Sanford E. Thompson; Harry D. Tiemann; William J. Tretch; N. B. Trist; United States Gutta Percha Paint Company, represented by H. W. Rice; C. P. Van Gundy; Hermann Von Schrenk; S. S. Voorhees; Watson Vredenburgh, Jr.; J. E. Wadsworth; Samuel Tobias Wagner; Joseph F. Walker; Percy H. Walker; William H. Walker; Lee W. Walter; Frank E. Washburn; George L. Waterhouse; George S. Webster; William R. Webster; Westinghouse Electric and Manufacturing Company, represented by C. E. Skinner; G. D. White; Max H. Wickhorst; The A. Wilhelm Company, represented by Walter S. Davis; H. V. Wille; Winchester Repeating Arms Company, represented by R. L. Penny; R. D. Wood and Company, represented by Walter Wood; Walter Wood; Julian E. Woodwell; Joseph R. Worcester; Wyman and Gordon Company, represented by George F. Fuller; J. B. Young.

Total number, 229 (including representations); total number in personal attendance, 217.

FIRST SESSION.—THURSDAY, JUNE 20, 3 P. M.

Business Meeting.

President Charles B. Dudley in the chair.

The minutes of the Ninth Annual Meeting were approved as printed.

The annual report of the Executive Committee was adopted as printed.

The Chair appointed Mr. Richard L. Humphrey and Mr. W. P. Taylor as tellers to canvass the ballot for officers.

A paper by Mr. P. H. Knight and Mr. C. E. Skinner, entitled "The Raw Material Supply," was read by Mr. Skinner.

The annual report of Committee J on Standard Specifications for Coke, Mr. Chas. H. Zehnder, Chairman, was read and passed to publication.

The following papers were then read and discussed:

"The Purchase of Coal Under Specifications." J. E. Woodwell.

"The Recent Testing of Coals Used by the Federal Government in its Public Buildings." J. A. Holmes and D. T. Randall.

"Methods of Testing Coal." S. S. Voorhees.

"Cast Iron—Some Causes of Failure in Service." Robert Job.

"Notes on Brick Pier Tests," James E. Howard, was read by title.

The report of Committee Q on Standard Specifications for the Grading of Structural Timber, Hermann Von Schrenk, Chairman, was then presented.

On motion, the following proposed Standard Specifications were referred to letter-ballot:

"Definition of Defects."

"Standard Names for Structural Timbers."

"Standard Specifications for Bridge and Trestle Timbers."

The tellers reported that 154 legal ballots had been cast, and in accordance with their report the Chair declared the election of Mr. W. A. Bostwick and Mr. William R. Webster as Members of the Executive Committee.

The meeting then adjourned until 8 P. M.

SECOND SESSION.—THURSDAY, JUNE 20, 8 P. M.

President Charles B. Dudley in the chair.

The Chairman invited the Vice-President, Mr. Robert W. Lesley, to the chair and read the Annual Presidential Address on "The Enforcement of Specifications."

The following papers were then read and discussed:

"Tests of Concrete Columns." A. N. Talbot.

"Some Additional Notes on Tests of Concrete Columns." James Howard.

"The Testing of Wooden and Reinforced Concrete Telegraph Poles." Robert A. Cummings.

Mr. Allerton S. Cushman then presented a paper on "The Corrosion of Iron."

A paper on "The Influence of Stress Upon the Corrosion of Iron," by Mr. W. H. Walker and Mr. Colby Dill, was read by title.

The meeting then adjourned till the following morning.

THIRD SESSION.—FRIDAY, JUNE 21, 10 A. M.

Section on Preservative Coatings.

President Charles B. Dudley in the chair.

The report of Committee E on Preservative Coatings for Iron and Steel, Mr. S. S. Voorhees, Chairman, was read and discussed.

Mr. E. P. Cheesman then read a paper on "Priming Coats for Metal Surfaces."

A paper by Mr. L. S. Hughes on "Deleterious Ingredients in Paints," was presented and the discussion opened by Mr. G. W. Thompson and Mr. F. P. Cheesman.

Mr. R. S. Perry read a paper on "The Physical Properties of Paint Films."

In the absence of the author, a paper on "Physical Testing of Varnishes," by Mr. J. C. Smith, was read by title.

A paper entitled "Paint Legislation," was then presented by Mr. E. F. Ladd.

The report of Committee H on Standard Tests for Lubricants, Mr. A. H. Gill, Chairman, was read and passed to publication.

The meeting then adjourned till 3 P. M.

Section on Cement.

Vice-President Robert W. Lesley in the chair.

The report of Committee C on Standard Specifications for Cement, Mr. George F. Swain, Chairman, was read and discussed.

The following papers were then presented and discussed:

"Avoidable Causes of Variation in Cement Testing." E. B. McCready.

"Some Problems of a Cement Inspecting Laboratory." R. S. Greenman.

"The Specific Gravity of Portland Cement." R. K. Meade.

"The Control of Physical Test Results in Portland Cement." W. A. Aiken.

"The Effect of Oil on Concrete." R. C. Carpenter.

"Labor-Saving Devices in a Cement Laboratory." R. E. Bakenhus.

"The Structural Materials Testing Laboratories, U. S. Geological Survey: Progress During the Year Ending June 1, 1907." R. L. Humphrey.

The meeting then adjourned till 3 P. M.

FOURTH SESSION.—FRIDAY, JUNE 21, 3 P. M.

President Charles B. Dudley in the chair.

Committee A on Standard Specifications for Iron and Steel, W. R. Webster, Chairman, presented a report on the proposed revised Standard Specifications for Steel Rails.

A general discussion on Steel Rails was opened by Mr. W. R. Webster.

The following papers bearing directly on this discussion were then presented:

"Rail Steel as Manufactured by the Continuous Open-Hearth Process." Benj. Talbot (read by the Secretary).

"Specifications and Inspection of Bessemer Steel Rails." M. T. Jones (read by the Secretary).

"Mechanical Experiences with Limber and Stiff Rail Sections." P. H. Dudley.

After a general discussion, the proposed revised Standard Specifications for Steel Rails, were, on motion, referred to letter-ballot of the Society.

The following three papers were read by title:

"Segregation in Steel Ingots." H. M. Howe.

"Effect of Conditions of Rolling on Certain Properties of Steel." H. M. Howe and William Campbell.

"The Heat Treatment of Steel." William Campbell.

The meeting then adjourned till the following morning.

COMPLIMENTARY DINNER TO PRESIDENT DUDLEY.

On the evening of Friday, June 21, a largely attended complimentary dinner was tendered to President Dudley at the Hotel Traymore. The occasion was graced by the presence of Mrs. Dudley and other ladies of the party. Vice-President Lesley presided, and acted as toast-master.

At the close of the dinner a silver loving cup was presented to President Dudley, on behalf of the members of the Society, by Secretary Marburg. After feeling words of acknowledgment on the part of President Dudley, the following toasts were responded to:

"Our Cradle Days." Past-President Mansfield Merriman.

"Our Ladle Days." Capt. Robert W. Hunt.

"Our Friends of the Technical Press." Mr. Willard A. Smith.

"Our Friends—The Manufacturers." Mr. George E. Thackray.

"Our Technological Brethren." Dr. William F. M. Goss.

FIFTH SESSION.—SATURDAY, JUNE 22, 10 A. M.

Section on Iron and Steel.

President Charles B. Dudley in the chair.

On motion of Mr. S. S. Voorhees it was resolved that the Executive Committee be instructed to consider the appointment of a Committee on Standard Specifications for the Purchase of Coal.

Mr. E. L. Hancock then presented a paper on "Results of Tests of Staybolt Iron."

The proposed Standard Specifications for Staybolt Iron, as reported by Committee M, Mr. H. V. Wille, Chairman, were, on motion, referred back to the Committee for further consideration, with instructions to state in the report at the next annual meeting the reasons for and against any clauses not unanimously approved by the members of the Committee.

The annual reports of the following committees were then read and discussed:

Committee T, on the Tempering and Testing of Steel Springs and Standard Specifications for Spring Steel. J. A. Kinkead, Chairman.

Committee O, on Uniform Speed in Commercial Testing. Paul Kreuzpointner, Chairman.

Mr. G. H. Clamer read a paper on "The History and Development of the Alloy Practice in the United States as Applied to Railway Bearings."

A paper entitled "Compressive and Transverse Tests of Steel Connecting Rods for Locomotives," was then read by Mr. Gaetano Lanza.

In the absence of the author a paper on "Tension Tests of Steel Angles," by Mr. F. P. McKibben, was read by title.

The meeting then adjourned till 3. P. M.

Section on Concrete, Fireproofing and Waterproofing Materials.

Vice-President Robert W. Lesley in the chair.

The annual report of Committee I on Reinforced Concrete, Mr. F. E. Turneaure, Chairman, was read by Mr. R. L. Humphrey.

The proposed Standard Test for Fireproof Floor Construction, reported by Committee P on Fireproofing Materials, Mr. Ira H. Woolson, Chairman, was, on motion, referred to letter-ballot of the Society.

The following papers were then read and discussed:

"Investigation of the Thermal Conductivity of Different Concrete Mixtures, and the Effect of Heat upon their Strength and Elastic Properties." Ira H. Woolson.

"Effect of Time Element in Loading Reinforced Concrete Beams." W. K. Hatt.

"Tests of Twisted Steel Square Rods for Concrete Reinforcement." J. J. Shuman.

"Tests of Bond between Steel and Concrete." T. L. Condron.

The annual report of Committee S on Waterproofing Materials, Mr. W. A. Aiken, Chairman, was read and accepted.

The meeting then adjourned till 3. P. M.

SIXTH SESSION.—SATURDAY, JUNE 22, 3 P. M.

Mr. Mansfield Merriman in the chair.

The annual report of Committee K on Standard Methods of Testing, was read by Mr. Gaetano Lanza, Chairman.

Mr. S. W. Stratton then presented a paper entitled "The National Bureau of Standards."

On motion of Mr. Skinner, the question of cooperation on the part of the Society with the Natural Bureau of Standards, was referred to the Executive Committee for consideration.

The following papers were then read and discussed:

"The White-Souther Endurance Machine." H. Souther.

"Notes on the Endurance of Steels under Repeated Alternate Stresses." J. E. Howard.

"Effect of Combined Stresses on the Elastic Properties of Steel." E. L. Hancock.

"A Concrete Dampcloset." E. McCready.

"A New Impact Machine." L. W. Page.

"The Development of the Penetrometer as Used in the Determination of the Consistency of Semi-Solid Bitumens." Clifford Richardson and C. N. Forrest.

"Multiplying Dividers for Locating Yield Point." J. A. Capp.

"An Instrument for Measuring Deformation in Tests of Materials." H. F. Moore.

"Comments on a Direct Reading Magnetic Tester." A. H. Taylor. (Read by title.)

On motion of the Secretary the meeting passed a vote of thanks to the Management of the Steel Pier for its courtesy in placing the pier at the disposal of the Society during the meeting.

The Chairman thereupon declared the meeting adjourned *sine die.*

AMERICAN SOCIETY FOR TESTING MATERIALS.

AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

PROCEEDINGS.

This Society is not responsible, as a body, for the statements and opinions advanced in its publications.

THE ENFORCEMENT OF SPECIFICATIONS.

ANNUAL ADDRESS BY THE PRESIDENT.

In the early days of specifications, they were little more than attempts on the part of the consumer, to tell the producer what he wanted. Some specifications which we have seen consisted of only a few lines and these either related almost entirely to a brief description of the material desired or embodied some simple tests. Indeed in the preparation of such specifications there is reason to think that the consumer himself had meager information in regard to the material he was describing and perhaps only knew with certainty that the material he was receiving was unsatisfactory and that he wanted something different.

Later on, as knowledge of materials increased, as methods of testing became better understood and more completely worked out, as those who were making specifications learned by experience, how difficult a matter it is to draw a satisfactory specification and especially after it became the custom to consult the manufacturer in making the specification, it took on a new meaning. At first it was a demand; it now became an agreement. At first it was ofttimes perhaps promulgated with something of a feeling of superiority by its maker, and was received by the manufacturer or producer with a feeling of opposition and antagonism, it now became more of a compromise and was put forth and received with a much more conciliatory spirit on both sides. From being a species of legal instrument that had in it conditions and requirements that the one who held the purse strings felt that he had a right to insist on, it took on more the nature of a contract in which the stipulations had practically been agreed upon by both parties in interest.

Looking at the specifications in this light and assuming, as we must, that business to be successful must be conducted in accordance with the principles of honesty, integrity and fair dealing, it would almost seem that it would be a waste of time and effort to discuss the subject which we have chosen for this paper "The Enforcement of Specifications." The specification is a contract and, as we have said again and again, in any properly drawn specification both parties have had a voice, differences have been harmonized and the conditions and stipulations have been agreed upon. If now, men are honorable and intend to do as they have agreed, as we are bound to assume that they are and do intend to do, what need is there for enforcement? Is it not safe for the consumer to receive and put into use the material which the producer furnishes without the trouble and expense of maintaining a department or a corps of inspectors, to protect his interests? Unfortunately the experience of the business world at the present time does not seem to warrant such a procedure. I doubt not there are consumers within the sound of my voice, who, if pressed for an answer to our question, would say with a somewhat sarcastic smile that the situation is utopian and that with human nature as it is, it is absurd to expect to get what you have contracted for, unless people are watched. On the other hand, no doubt an equal number of producers who hear me, are entirely ready to assert that they are conducting their business in such a way and are making and delivering such a product, in their specification material, that any consumer would be absolutely safe in receiving and using it without inspection. For our own part, as the result of an almost daily experience for some thirty years with specification material, we are compelled to side with the consumers and to maintain the necessity for inspection and tests.

And lest by this statement we should seem to call in question the business integrity of the producers, among whom we are happy to number some of our best and most valued friends, let us hasten to say that there are so many conditions leading to the manufacture and delivery of unsatisfactory materials, that is materials that do not fill the requirements of the specification on which they were bought, which conditions do not involve the business integrity or the honest intention on the part of producer to do as he has agreed, that we are sure no one need feel aggrieved at the establishment and maintenance by consumers of devices for the enforcement of their specifications. It would of course lead us too far to inject into this paper a discussion of business honesty on high moral grounds. Such a discussion is foreign to our present purpose. The basis of our discussion is the business truism, that a transaction is satisfactory when both parties get benefit from it and both parties are satisfied. No one believes more devoutly than we do, that with few exceptions, so few as to be almost ignorable, producers in general prefer to do an honest business at a fair price and profit and that they always would do so, if it were not for certain conditions. What then are some of these conditions?

First, however, in order to avoid constant repetition of the words " materials according to specifications," and "not according to specifications," let us agree that the former may be properly designated as "satisfactory materials" and the latter as "unsatisfactory materials," the view point obviously being that of the consumer. This being granted, the first condition that we will consider which leads to the tender of unsatisfactory materials is improperly worded or unreasonable specifications. It is obvious that the view point of those having to do with either the making or carrying out of specifications being different and in a sense antagonistic, since their interests are naturally and legitimately opposed, the meaning which they attach to words will be different and both parties may be equally honest. We knew of a case once where a lumberman agreed to buy a large number of logs from the owner of a valuable timber tract on the simple specification that only two logs from a tree should be delivered. Imagine his surprise when the logs began to come in to find them small, tapering and full of knots. On remonstrating he was told that just exactly as the specification called for only two logs per tree were being delivered and he was invited to look at his contract. An inspection revealed the fact that although the lumberman undoubtedly had in mind when the specification was drawn that he should receive two logs from the butt of each tree, the important word "butt" had been left out; while on the other hand, the owner of the lumber tract had unquestionably read into the specification when it was presented, that under it he would be entitled to deliver two logs from the top of the tree, just as he was actually doing. It may not be unwise to add that a contract covering two butt logs from each tree was somewhat unusual, that the price was lower than would have been expected for such logs and that as a matter of fact the case never came into court. In like manner an unreasonable requirement in a specification may lead to the same result. Our friends the steel manufacturers are constantly being presented with specifications containing stipulations which it is impossible or at best only occasionally possible to fill. Those who have made these specifications have, it is true, we fear neglected one of the prime requisites of a good specification, viz., to consult with and on certain technical points be guided by the best manufacturers. And it may be urged that a producer has no right to take a contract under a specification that contains a requirement that he knows he cannot fill. While this is true abstractly, it must be remembered that the producer is in a rather delicate situation. If he remonstrates aganist the unreasonable requirements, he probably loses a customer. If he refuses to take the contract with the unreasonable requirement, and as a matter of fact it is well known that this is done again and again, he not infrequently makes an enemy of the engineer or expert who simply has a crotchet in his head, but is otherwise a very good fellow and who later may be valuable; so the contract is taken, even with the unreasonable requirement and with the thought in mind of getting along with the matter in the best way possible if any difficulty should arise. The producer we fancy knows that he is making good material and giving good value and with this thought condones himself for his seeming breach of contract. As far as our subject is concerned we cannot but feel that an improperly worded or an unreasonable specification is a most potent cause for the tender of unsatisfactory materials.

Again the mistakes of subordinates are a frequent cause for the same difficulty. An illustration of what we mean by mistakes of subordinates will make the matter clear. Some years ago a railroad company placed an order with a most reputable firm for fifty barrels of the best grade of lard oil, known at the time as "Extra" or "Prime," the other well-known grades being Extra No. 1, No. 1, No. 2, and No. 3. The difference in the cost of the extreme grades was ten to fifteen cents per gallon. The order was what is technically known as a "Rush" order, that is, to be filled as soon as possible. In due time the material arrived at destination and was sampled and tested in the regular way. The test showed the material to be No. 3 oil and the shipment was promptly rejected and returned to the shippers. They made a careful examination of the shipment barrel by barrel, and found that forty-five barrels contained oil of the proper grade and of unexceptional quality, while the five barrels were No. 3 grade as the test had shown. On asking for an explanation, the foreman of the works said that when the order was received he only had forty-five barrels of the proper grade in stock and it being a rush order he put in five barrels which he knew to be inferior, hoping that the matter would escape detection. It may be of interest to know that in this case the shippers actually felt themselves aggrieved and claimed that since they had to pay return freight on rejected material the forty-five barrels of good oil should have been retained and only the five barrels of inferior oil should have been returned. The purchasing agent on the other hand very mildly, but very firmly, reminded the shippers that the order which he had placed with them did not call for any No. 3 oil, that there was a difference in price of at least $5.00 a barrel between the two oils and that if perchance the sample tested had come from one of the barrels of good oil, the shipment would have been accepted without question and it would have been a clear case of successful fraud by which they would have profited. But there was considerably more in this case, than was brought out by the purchasing agent. Extra or prime lard oil is used by railroad companies almost exclusively in making what is technically known as "Signal Oil," that is, oil used in signal lights and in trainmen's lanterns; also the safety of trains and even the lives of passengers depend on the reliability of the signal oil and perhaps more important still a signal oil made of No. 3 lard oil is utterly worthless and unreliable. The lanterns will commonly go out and fail completely within two hours after new trimming and filling with such oil. The bearing of all this on the necessity for the enforcement of specifications is too evident to require comment.

It would lead us wide of our proper field to raise and discuss the question whether such a mistake on the part of subordinates, as we have cited, is ever made with the knowledge and consent of the principals or not. We have heard it intimated that such transactions are fairly common and that when such a case comes to the knowledge of the office or the principals, one of two things is apt to result. If the shipment has gone through, the transaction is closed and no questions have been raised, the subordinate is usually not reprimanded, but on the contrary gets a smile of approval. On the other hand, if the fraud is detected and trouble and loss result, the subordinate not infrequently suffers.

Perhaps you will bear with me while I give another out of the many that might be cited of the conditions leading to the tender of unsatisfactory materials, even though those who are doing so, have a sincere and honest intention of fully meeting the requirements. This condition is that commercial processes do not always yield what is expected of them. Something in the materials used, or in the processes employed, gives a product that is unsatisfactory, notwithstanding the producer supposed he had done everything that he could to secure a successful result. Let me give an illustration. Some years ago in our laboratory at Altoona, we examined in the regular way a sample representing a shipment of phosphor-bronze bearing-metal from a firm whose business reputation and character were simply above reproach. This material, as is well known, is an alloy of copper, tin, lead and phosphorus, the percentages of each constituent being fixed within narrow limits by the specification. The analysis showed copper, tin and lead within the limits, but no phosphorus, and the shipment was rejected. This was followed by a visit from one of the principals of the firm, who maintained that he had actually purchased in the market phosphor-tin at a high price and used it in making this very material and that the fact that we found no phosphorus was a mystery to him. It was asked if he knew by analysis how much phosphorus there actually was in this so-called phosphor-tin, since our own analyses of the material in the market showed not over a third or at most half of what was claimed. He confessed that no analyses had been made, but stated that he bought the material on a guarantee that it contained ten per cent. He was then asked if he knew that there was a loss of phosphorus every time the alloy was melted and that with careless foundry manipulation this loss might readily amount to all the phosphorus he had actually added. His reply indicated haziness on the subject, coupled with a desire to learn. A few suggestions were eagerly noted and apparently well applied, since the same firm subsequently made and furnished to the road large quantities of entirely acceptable material.

And so we might go on quite at length, detailing condition after condition that leads to the tender of unsatisfactory materials, some of them perhaps not quite as free from suspicion as those already mentioned, but all of them emphasizing the necessity on the part of the consumer of apparatus and appliances for testing and a rigid enforcement of specifications. It will, perhaps, be sufficient if we enumerate without special illustration or comment, a few more of these conditions. A contract taken at too low a figure is a fertile cause of what we have agreed to call unsatisfactory materials. Under stress of competition agreements are made that if carried out strictly in accordance with the specifications, would result in loss, or lack of reasonable profit. Again, strange as it may seem, a very large number of manufacturers of commercial products as a matter of fact do not know the characteristics of their output. They have been making and selling their staple for a period of years, it may be, and as long as the consumers accepted the material and raised no questions, they themselves saw no need of making tests and experiments, except perchance such as would lead to diminution of cost in manufacture. Accordingly, very little or no knowledge was obtained of those qualities of the material which are of most interest to the consumer. It has been our custom for many years, as is well known, to send our proposed specifications to the manufacturers for criticism before they are officially issued and we have again and again received from producers in reply to the question whether they could make a product that would stand the tests of the proposed specifications, the answer, that they could if anybody could. There was apparently absolute lack of even the most rudimentary knowledge of those qualities of their product, which were of the most interest and importance to the consumer. And yet, without this knowledge, contracts are taken and shipments made. What more natural than that the material should be unsatisfactory in the technical sense of the word? Again the tender of unsatisfactory material is often explained, after it has been tested and found wanting, by the statement that although it may not quite fill the requirements it still is good material and will do the work. Of course it takes but a moment's reflection to lead any fair-minded person to the conclusion that this statement is not at all the question at issue and that if the consumer had been willing to use a material that is, in the language of the shops "just as good," he would have specified such material and obtained the benefit of a corresponding variation in price.

Two more conditions leading to unsatisfactory materials may perhaps wisely be mentioned before we leave this phase of our subject. It not infrequently happens after a contract has been made, that unexpected and wholly unforeseen difficulties arise in securing raw materials from which the product in question is made. An unexpected demand has sprung up for that kind of raw material, making it scarce in the market, or the parties with whom the producer has a contract for his supply repudiates the contract, or there has been an accident or catastrophe affecting the supply. The producer, therefore, finds himself in the condition that either he is unable to make deliveries as he has agreed to do or he must, or thinks he must, make deliveries of his product containing such raw materials as he can get with the accompaniment of that brood of troubles that arise when the tests show unsatisfactory materials. Not once but many times has this situation been prominent in the course of our work at Altoona; and there is one phase of the matter which we have found it most difficult to understand. The producer goes ahead and makes up his product from inferior raw materials and makes shipments, knowing that there will be trouble; and then when the trouble arises, he explains and asks for leniency. The query in our minds has always been, why does he not explain and ask for leniency before he makes and ships the unsatisfactory material? If we may trust our experience, a frank statement of the situation beforehand would be far the wiser course. We fancy the reasons for the procedure actually followed will ever remain one of those business mysteries, which are incomprehensible to the lay mind.

Finally, a most common and pestiferous cause of the tender of unsatisfactory material is the statement that delay must follow if these unsatisfactory materials are not received and used. We say pestiferous, because of all the causes leading up to the tender of unsatisfactory materials, this one seems to us to have the least foundation of equity to rest on and to be the one that smacks most strongly of a deliberate effort to force through an acceptance, regardless of quality. We are quite well aware that emergencies may arise in the case of those who are furnishing materials, which emergencies may fairly be regarded as legitimate causes for an unsatisfactory product. We have already discussed a number of such. On the other hand we have so many times had occasion to feel that at the last minute, materials are tendered, which the parties had known for some time, or at least might have known, were inferior and not satisfactory, that the argument that there will be delay if you do not accept this that we tender is deprived in our minds of a very large precentage of its force. It would be infinitely better, it seems to us, not to make shipments and either to put some of the energy now employed in trying to get unsatisfactory shipments accepted, into making and furnishing satisfactory material or to make a frank statement of the situation to the consumer beforehand and abide his decision. Such a statement would do much toward smoothing down and removing some of the roughnesses and inequalities of the road which the producer and consumer are trying to travel together, toward the goal of a successful financial transaction.

Let us now turn to another phase of our subject. If we have succeeded in what has been said, it is evident that there is necessity for the enforcement of specifications and that too without assuming that men are dishonest or do not intend to do as they have agreed. Under present commercial conditions and with our present knowledge of the properties of materials, and of the processes by which they are made, it simply would not do for the consumer to leave his interests wholly in the hands of the producer. Each must look out for his own interests and be prepared to defend and maintain them. Perhaps we have said more than is necessary on this point, but the practice of buying and using materials on the reputation of the maker is so deep-seated and wide-spread, and has for so many years been the refuge of engineers in cases of failure, that perhaps the subject will safely bear elucidation at a little greater length than would otherwise have been admissible.

But how shall specifications be enforced? What are the essentials of successful enforcement? We reply, first, the examination and testing of the material tendered must be so planned as to be efficient and leave no loop-holes for evasion or substitution of inferior materials. In the case of some substances every shipment must be tested. In the case of others, as for example, materials that are produced in heats or are stored in tanks or bins, the tests deciding their fate may be construed to cover the whole amount even though there may be a number of deliveries. The essential feature is that each test or lot of tests, shall cover a definite amount of material and that nothing shall be left to the honesty and good intention of the producer or shipper. If we are going to trust the producer in one detail we may as well trust him in all. The strength of a chain is the strength of its weakest link. No universal rule can be given, but assuming that the specification is wisely drawn and provides only essential tests, these tests must be so applied as reasonably to cover all the material that is delivered.

Again, since it is clearly impossible, except perhaps in the case of proof strains, to apply tests to all the material in the shipment, it is obvious we must rely on tests of samples, and this brings up the question of sampling. Upon this point several rules are clearly applicable. First, a representative of the consumer must always take the sample. This is in accordance with the principle already enunciated that it is not reasonable or proper or safe to trust the producers in anything by which the validity of the tests might be affected. Not once but many hundred times have we been asked to allow the shippers or producers to send a sample and accept a shipment on its examination. The request was undoubtedly made in good faith and with no other desire than to facilitate the transaction. Perhaps it is needless to say that our belief in the facility with which unintentional mistakes would be made and a sample better than the average of the shipment be sent, has always led us to positively refuse such requests.

Second, the sample must be representative of the whole shipment or lot under test. This point is usually provided for in the specifications and does not here require special comment. Nor is it essential perhaps to remark on the necessity that the sample should represent a definite amount of material, since this is also provided for in the specifications. We may, however, be permitted to say that some specifications that we have seen, seem to us to assume greater uniformity in the product made in successive similar operations, than actually exists in the material. If it were at all possible to avoid it, we would not like to accept articles of steel made by the Bessemer process, especially where strength and safety are involved, without a test of each blow.

A third point in regard to sampling has a more direct bearing on our theme, the enforcement of specifications, viz., the sample should be taken at random and not always from the same place. We have many times been surprised to find out how intimate the knowledge on the part of the shipper or producer soon gets to be of the practices of the consumer in sampling. Apparently the producer thinks it is just as fair that he should know all about the consumer's use of his material, as that the consumer should know all about his manufacture of it. This we are quite ready to concede. But now if in sampling a car load of oil the barrel next to the door is always chosen by the inspector or if in sampling a pile of axles the one on top is always selected or in picking out a spring for test from a lot assembled and offered if the one nearest at hand is habitually taken, it is perfectly evident that an opportunity is afforded for one of those unintentional mistakes of workmen or foremen that would result in the best material always being tested. It would take us too far away from our subject to discuss here the bearing upon these unintentional mistakes of the practice which is so common in many establishments of paying the subordinates, nay even the whole manufacturing organization perhaps, in proportion to the amount of successful output. We cannot but think, however, that ingenuity in sampling is a legitimate and reasonable offset to this practice and that it is as important that the inspector who takes the samples should be full of suspicion and scientific doubt, as that testing machines should be reliable, or that a chemical balance should give accurate weights.

As showing how failure to comprehend the whole shipment in the sampling may result in disaster and at the same time illustrate, the unintentional mistakes of workmen about which we have already said so much, let us cite an incident. A lot of bronze castings were being furnished for use in locomotive construction. The order was a large one and shipments were made from time to time. The inspection force was pressed with work and, let it be confessed, not quite as much permeated with suspicion and scientific doubt as should have been the case. The bronze was bought on definite chemical specifications and from each delivery enough sprues were broken off from various castings by the inspector to properly sample the material. These samples were used for the analysis. Deliveries were made usually about three times a week and the inspector was sent for to inspect and sample the material whenever a delivery was ready. It was explained to the inspector that it would greatly facilitate the work of the foundry if he would allow say, three-fourths or more of the castings to have the sprues broken off and used over again, before the regular sampling was done. They would leave enough sprues attached, say to a quarter of the castings (nothing very definite as to the number of sprues to be left attached was promised) so that he would have abundant chance for selection. In the goodness of his heart the inspector allowed this to be done. A number of shipments were made, sampled, tested and accepted in this way. Some suspicion having arisen later in the minds of those higher up than the inspectors in the testing organization, some twenty full size castings, all selected from a large number of those from which the sprues had been broken off before sampling, were sent for analysis. The analyses showed that in some manner not explained every one of the samples from the castings bereaved of their sprues by the foundry force were not only not according to the specifications, but showed unmistakable evidence of having in their composition large percentages of inferior scrap. It is perhaps needless to add that from this time forward, after the inspector had been changed, the sprues were all allowed to remain on all castings until the sampling was finished.

This brings us to the last requirement in sampling which we will discuss, viz., the sampled material should, as far as possible, not remain in the hands of the producers after it has been sampled. The equity of this practice will not, we fancy, be called in question; the actual carrying out of the rule is not always so easy. Materials that are sampled and tested, after they arrive at destination, present no difficulties. We have known of refusals to ship, until after the material had been tested and accepted, but when it was explained that it would be practically impossible to send inspectors to sample every shipment of every kind of material before it was started on its journey to the service for which it was intended, such refusals have usually vanished. Moreover, the refusal to ship has always seemed to us to argue, either a lack of knowledge of the characteristics of the material that the shipper is tendering, or a well grounded fear that it would not stand test. Also, in the case of materials such as springs, alloys, etc., which can be inspected and sampled and then loaded at once, there is no difficulty, but in the case of materials which cannot be so treated or which must be stored the matter is more serious. In such cases, marking in such a way that the marking cannot be defaced without showing it, must always be practiced. The chances for unintentional mistakes are too numerous and the fact that such mistakes do actually frequently occur is too common to permit of any uncertainty on this point.

Before leaving the subject of sampling, perhaps you will bear a word on the question whether a sample taken with all the known precautions does as a matter of fact, actually represent the shipment. The sample is but a very small fragment of the shipment, and a doubt may fairly be felt as to whether the whole shipment is like the sample. It is obvious that if the specification is intelligently drawn all the variations in the material, due to uncertainties in the process of manufacture or unavoidable errors of manipulation, are provided for in the sampling which it directs. This leaves only intentional or unintentional variations, introduced by the producer, to be provided against. Our position in regard to these has always been that if the producer was willing to take the risk of our getting our sample from one of these intentionally inferior parts of the shipment, with the rejection which would inevitably follow, we were willing to take the chance of getting a sample from a better part of the shipment, with the consequent acceptance of some inferior material. Moreover, in cases of reasonable doubt we have a number of times sampled every part of a shipment and are strong in our belief that very few commercial men would persistently offer material, portions of which they knew to be inferior.

But again let us discuss another phase of our theme. Let us assume that the specification has been wisely drawn, that a shipment has been properly sampled and that the tests show that it does not fill the requirements. What is the next step? As a matter of fact in our own daily work, but one thing is ever done and that is the material is rejected. None of our specifications provide for a second or third sampling and corresponding tests. Our theory is that the material ought all to be of the grade called for by the specifications, since this is what the consumer has bargained for, and if this is the actual fact one sample is as good as fifty. We are quite well aware that there are many specifications in force which provide for second and, if need be, third tests, the fate of the shipment to be decided by the majority. But this has for a long time seemed to us to be a survival of the crude early days of testing, when neither producer or consumer knew much about materials and which it is high time should be banished forever. If a specification is so severe that only two-thirds of well-made material will stand test, the specification should be changed and if a manufacturer can only make a product, two-thirds of which will stand test, he should either learn how to improve his product or go out of business. Testing was never intended to be a device to bring about the acceptance of inferior material; but quite the contrary. Moreover, from three samplings and tests it is but a step to five or seven or nine and perhaps if sampling and test is long enough indulged in a majority may ultimately be found which will always bring acceptance of the material. Surely the interests and responsibilities of the consumer cannot be trifled with in this manner.

But some one says, are you so sure that you are right in your single test that you feel that you are on firm ground in rejecting material and cutting off all chance for further tests? We reply that is quite another matter. Retesting because the material fails, no question being raised in regard to the reliability of the tests, is entirely different from a retest because there is reason to think there is something wrong with the sampling or testing. In this case the burden of proof is on the producer and it is incumbent on him to show reasonable ground for re-opening the case. On the other hand, it is equally essential that the consumer should welcome the investigations of the producer; should throw everything open to him, and give him every facility for satisfying himself that no injustice has been done. There is no room for a star chamber in the enforcement of specifications. In our own laboratory, we always keep the sample of every rejected shipment for a month and are always ready to give the producer half of our sample for verification purposes. Moreover, we have often said to shippers who were interviewing us over rejected material "you may follow your material from your works to destination, you may see the sampling, may follow the sample to the Laboratory and either by yourself or your technical representative be present and watch the whole operation of the testing, and, finally, here is half the sample on which we have worked. Put it in the hands of any reputable chemist and if he does not confirm our results, we will take up the question with him and find out who is in error." Our sincere desire is to get at the truth and we cannot put it too strongly, there should be nothing unfair or secret or arbitrary on the part of the consumer in rejecting material. On the other hand, the sampling and testing being fair and honest and reliable, there should be but one sampling and testing and no retests.

Closely related to the point we have just discussed is the question of the use of rejected materials. It is safe to say that hundreds of times during the past thirty years, we have been asked, "Yes, it is true the material does not quite stand test, but cannot you accept and use it? And only a little less frequently the same request has been made of those higher in authority in the organization. The arguments usually used are, "the material will give you good service, not quite as good as if it had stood test, but still on the whole fairly satisfactory." Also "we are good friends of yours, and would do the same for you." And still further "we are very large shippers over your line, and think some concession is due to us in view of this fact." There is apparently complete failure on the part of those using these arguments to comprehend the position in which they are placing the officer to whom these requests are made. Let us see if we can look at the matter from his point of view. It takes but a moment's reflection on the part of any fair-minded person to enable him to see that to grant the request means a complete breaking down of the specifications. The officer in question is usually responsible for the specification. He has made and issued it and that too after careful consultation with those who are to furnish the material. The requirements of the specification have been agreed to and a contract has been made with the purchasing agent or other officer, to furnish material that would stand test. If now the specification is to be waived in one case, why not in all, and what then becomes of the specification? Still further, a shipment of the kind in question once accepted becomes a precedent for the next case and so on *ad finitum.* Moreover, apparently also another and very important point is forgotten, viz., that it is simply unfair and unjust to those who are furnishing material which does fully meet the requirements, to accept shipments from others who fail in this respect. Much of the obloquy which is so rife at the present time, affecting those in authority in large organizations using large quantities of material, is legitimately and reasonably based on cases of this kind. It is claimed, and as it seems to us justly so, that certain parties have a pull and are able to do business with the organization in question, while others who are striving to be absolutely straight forward and honest and to do as they have agreed, are entirely unsuccessful. Moreover, there is another phase of the case. It may chance that the rejected material is of such a nature that the use of it would only involve a slight financial loss. This point we will refer to in a moment. But again, on the other hand, the rejected material may be of such a kind that the question of safety to passengers or risk to human life, is involved in its use. In this last case it seems to us that there can be but one answer to the request to use unsatisfactory material and that is "nothing could induce us to accept and use this material." And in the case where only a money loss is involved, as has just been cited, we are clear that there is only one condition under which it is at all admissible to accept and use rejected material. It has been a puzzle to us how completely manufacturers and shippers lose sight of this condition. If among the arguments used to get the rejected material accepted the shippers would only urge "it is true the material is not quite what we have agreed to furnish and in view of this fact we will deduct a certain amount from the bill," their case would, as it seems to us, stand on firm ground and might have a reasonable expectation of success. Fairness and the ultimate satisfaction of both parties to a transaction is the only basis upon which successful business can be continuously carried on.

This whole matter of multiple tests, retests, and the disposal of unsatisfactory material can, as it seems to us, be summed up in a few words. Multiple tests are pernicious and should be abandoned. Retests, including the sampling, should never be made unless there is reasonable evidence to think there is an error somewhere in the first test, and to decide this point every reasonable facility should be furnished by the consumer to the producer to enable him to satisfy himself. Shipments or material once fairly rejected, should never be accepted and used if the material is of such a kind that safety or risk to human life is involved, and finally it is suicidal, as it brings with it a train of almost unmanageable subsequent conditions, to accept rejected material in which only commercial considerations are involved, unless there is some abatement in price.

A number of other points involved in the enforcement of specifications might be discussed, but I fear I have already wearied you. Perhaps you will bear with me while I very briefly touch upon one or two more. It not infrequently happens that when the tests are applied to the sample, it is found that it almost but not quite fills the requirements. What should be the procedure in such a case? The answer is not quite so easy as might seem at first sight. It is well known that the ruling which prevails in many locations, especially abroad, is that the material fails and should be rejected. For example, suppose the specification requires not above 0.040 per cent. of phosphorus in the steel, and the analysis shows 0.043 or 0.045 per cent. Shall the material be rejected? It is plain that the accuracy of chemical work is involved. Now it should be confessed openly and plainly that no test gives absolutely accurate results. One of my old instructors used to say "no chemist can make an absolutely accurate analysis." "Even though the chemist himself was infallible, the methods will not give absolute results." "There are chemists who can work near enough to accuracy so that their results are useful, and there are others who cannot." And the same is true of physical tests. Testing machines are not absolutely accurate and strictly accurate measurements are very difficult to make. How then shall these inevitable inaccuracies be handled?

In our own laboratory no shipment is ever rejected until the test has been duplicated and sometimes three or four tests are made. But this still leaves the unavoidable small inaccuracies unprovided for and they must be provided for in some way, as not rarely acceptance or rejection turns upon them. Two ways of meeting the difficulty have been suggested. One is to have it a part of the specifications and to have the producers clearly understand it, that the limits of the specifications cover the inevitable and unavoidable errors of testing, that is, the manufacturer should work far enough within the limits of the specifications, so that the inevitable and unavoidable errors of testing, would never lead to the rejection of a shipment. The other way is to make the limits of the specification sufficiently narrower or wider, as the case may be, to cover these unavoidable and inevitable errors of testing and then allow for them in deciding whether to accept or reject. The latter procedure is the one we have always followed in our laboratory. An illustration will make the whole matter clear. For certain purposes steel containing 0.040 per cent. of phosphorus will give us perfectly satisfactory results in service. But knowing as we do, that chemists will differ and that there are inevitable and unavoidable errors in the analysis, we make the upper limit of phosphorus in the specification 0.03 per cent., knowing that such steel can readily be obtained in the market without undue hardship to any one. It is evident we have by this procedure sufficient margin to cover inevitable and unavoidable errors in the determination, without raising questions which involve contention and hair splitting. It is infinitely better it seems to us, to so draw the specifications that the service will be protected by a sufficient margin to afford good strong fighting ground and then when a rejection is made stand by it to the bitter end. One of the most used rules of our laboratory is, never reject a shipment unless you know beforehand that, so far as the figures of the test are concerned, you will win in the contest which may follow the rejection.

Again let us suppose that a shipment has been wrongly rejected and that the shipper has been put to expense in regard to it. Is any requital due him for this loss or must he regard it as one of the inevitable expenses of doing business? We answer unhesitatingly that in the case supposed there is only one thing to be done and that is for the consumer to make good the loss due to the erroneous rejection. It is a poor rule that does not work both ways.

We should like to discuss several points further in connection with our theme, notably what shall become of rejected material? How far has the consumer a right to protect himself against such material and especially has he a right and is it good policy for him to so mark rejected material that it cannot be offered again? Still further, we should like to bring before you the question as to who shall make good the annoyance and frequent money loss which are experienced by the consumer due to rejected materials. It is always annoying and often necessitates expensive delays and re-arrangements to reject a shipment. Also what penalty, if any, should the producer pay to requite the consumer for this annoyance and loss. Our subject is not nearly exhausted, but we have already taken too much time.

Bear with us while we conclude by presenting very briefly a problem which has had lodgment in our own brain for quite some time now and which recent events in regard to certain materials have seemed to force into prominence. It is plain that in using materials in those constructions which involve safety in the railroad sense, or risk of human life in the public sense, there is a question of responsibility involved. If rails are defective and break, if an accident with loss of life results from the use of poor material in car construction, if a bridge falls and produces a disaster due to inferior materials, or a building collapses from the same cause, it is clear that some one should be held responsible; and since there are but two parties involved in the materials, viz., those who make them and those who accept and use them, it is difficult to see how one or the other of them is going to escape the responsibility. Now our problem is, which of the two in equity should be held responsible? It is perhaps hardly wise at this time to attempt a definite answer. Much might be said on both sides and probably no two persons, certainly neither of the two parties most interested, would give the same answer. But there is a phase of the case which we would like to present. It is well known that in the earlier structural work, when safety was involved, there was no testing worthy the name and materials were bought and used on the reputation of the maker. Fortunately the constructions in most cases had a high factor of safety. When disaster did come, if it was due to defective materials, it was explained that the materials used were from those of the highest reputation in the business, and that no one could really be held responsible. But at the present time conditions have changed. The knowledge of the properties of materials of construction has increased, methods of testing and testing appliances have grown up in delightful profusion and it is to-day entirely possible, we feel safe in saying, for an engineer to be reasonably sure that defective material does not go into his structures. We waive here the discussion of commercial considerations as affecting the use of materials. If it is shown that these have led to the use of defective materials, the moral responsibility for loss of life must certainly go to the one who has allowed commercial considerations to have such undue weight, be he either the maker of the material or the one high in authority who has allowed it to be used. But the point we want to make is, in view of present knowledge and present means and appliances for testing, are engineers or their principals any longer entitled to offer as an excuse for defective materials, that they were bought from the best makers? Can they equitably do so? Can they legally do so? Is not the time near at hand when engineers and their principals will be compelled if not legally then by force of public opinion, to acquire by the establishment of laboratories and means of testing, by the making and enforcement of specifications, such knowledge in regard to the materials they are putting into structures, as will give the public greater security than it now has against disaster.

REPORT OF COMMITTEE A ON STANDARD SPECIFICATIONS FOR IRON AND STEEL.

At the last annual meeting the report of Committee A on Standard Specifications for Steel Rails was referred back to the Committee with instructions to report at the next annual meeting proposed Standard Specifications for Steel Rails which would give promise of correcting as far as possible the defective quality of rails obtained under existing specifications.

In pursuance of that resolution, the Executive Committee appointed a sub-committee of Committee A to prepare a report on proposed standard specifications for steel rails.

This sub-committee, consisting of Messrs. W. A. Bostwick, P. E. Carhart, Charles B. Dudley, E. F. Kenney, Edgar Marburg, George E. Thackray and W. R. Webster, held two meetings, and unanimously agreed to reaffirm the recommendations with respect to Standard Specifications for Steel Rails made at the last annual meeting, with the following modifications:

1. *Discard.*—There shall be sheared from the end of the blooms formed from the top of the ingots not less than x* per cent. and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does.

2. *Straightening.*—To adopt the clause governing straightening in the specifications recommended by the American Society of Civil Engineers, adding the following sentence at the end of the first paragraph:

"The distance between supports of rails in the gagging press shall be not less than 42 inches."

This action was submitted to Committee A for letter-ballot which resulted in 22 affirmative votes sustaining the action of the sub-committee and 2 negative votes. The proposed Standard Specifications for Steel Rails are as follows:

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* The percentage of minimum discard in any case to be subject to agreement and it should be recognized that the higher this percentage the greater will be the cost.

PROPOSED STANDARD SPECIFICATIONS FOR STEEL RAILS.

ess of
ufacture.

(1) (*a*) The entire process of manufacture and testing shall be in accordance with the best current practice, and special care shall be taken to conform to the following instructions:

(*b*) Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled or until the metal in the interior has time to solidify.

(*c*) No bled ingots shall be used.

(*d*) There shall be sheared from the end of the blooms formed from the top of the ingots not less than x* per cent., and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does.

(2) Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

mical
position.

	50 to 59 Pounds. Per cent.	60 to 69 Pounds. Per cent.	70 to 79 Pounds. Per cent.	80 to 89 Pounds. Per cent.	90 to 100 Pounds. Per cent.
Carbon....................	0.35-0.45	0.38-0.48	0.40-0.50	0.43-0.53	0.45-0.55
Phosphorus, shall not exceed	0.10	0.10	0.10	0.10	0.10
Silicon, shall not exceed.....	0.20	0.20	0.20	0.20	0.20
Manganese	0.70-1.00	0.70-1.00	0.75-1.05	0.80-1.10	0.80-1.10

Test.

(3) One drop test shall be made on a piece of rail not less than four feet and not more than six feet long, selected from every fifth blow of steel. The test shall be taken from the top of the ingot. The rail shall be placed head upwards on the supports, and the various sections shall be subjected to the following impact tests under a free falling weight:

	Weight of Rail. Pounds per Yard.	Height of Drop. Feet.
	45 to and including 55	15
More than	55 " 65	16
More than	65 " 75	17
More than	75 " 85	18
More than	85 " 100	19

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* The percentage of minimum discard in any case to be subject to agreement and it should be recognized that the higher this percentage the greater will be the cost.

If any rail break when subject to the drop test, two additional tests, taken from the top of the ingot, will be made of other rails from the same blow of steel, and if either of these latter tests fail, all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted.

Finishing Temperature

(4) The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot-saws, for a 30-foot rail of 100 lb. section, of $6\frac{1}{16}$ inches, and $\frac{1}{16}$ inch less for each 5 lb. decrease of section. These allowances to be decreased at the rate of .01 inch for each second of time elapsed between the rail leaving the finishing rolls and being sawn. No artificial means of cooling the rails shall be used between the finishing pass and the hot-saws.

Drop Testing Machine.

(5) The drop testing machine shall have a tup of two thousand (2,000) pounds weight, the striking face of which shall have a radius of not more than five (5) inches, and the test rail shall be placed head upwards on solid supports three (3) feet apart. The anvil block shall weigh at least twenty thousand (20,000) pounds, and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made.

Chemical Analyses.

(6) The manufacturer shall furnish the inspector, daily, with carbon determinations for each blow, and a complete chemical analysis every twenty-four hours, representing the average of the other elements contained in the steel, for each day and night turn. These analyses shall be made on drillings taken from a small test ingot.

Weight Section.

(7) Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with paragraph (8) relative to specified weight. A variation in height of one-sixty-fourth ($\frac{1}{64}$) of an inch less, or one thirty-second ($\frac{1}{32}$) of an inch greater than the specified height, and one-sixteenth ($\frac{1}{16}$) inch in width will be permitted.

(8) The weight of the rails will be maintained as nearly as possible, after complying with paragraph (7) to that specified

in contract. A variation of one-half ($\frac{1}{2}$) of one per cent. for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

Length. (9) The standard length of rails shall be thirty (30) feet. Ten per cent. of the entire order will be accepted in shorter lengths, varying by even feet to twenty-four (24) feet, and all No. 1 rails less than 30 feet shall be painted green on the end. A variation of one-fourth of an inch in length from that specified will be allowed.

(10) Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs.

Finish. (11) *Straightening.*—Care must be taken in hot-straightening the rails, and it must result in their being left in such a condition that they shall not vary throughout their entire length more than 5 inches from a straight line in any direction, when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as second-quality rails and be so stamped.

The distance between supports of rails in the gagging press shall be not less than 42 inches.

Rails shall be straight in line and surface when finished—the straightening being done while cold—smooth on head, sawed square at ends, variation to be not more than $\frac{1}{32}$ inch, and, prior to shipment, shall have the burr occasioned by the saw cutting removed, and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds.

Branding. (12) The name of the maker, the weight of rail and the month and year of manufacture shall be rolled in raised letters on the side of the web, and the number of blow shall be plainly stamped on each rail where it will not subsequently be covered by the splice bars.

Inspection. (13) The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times when the contract is being filled, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with the terms of these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment.

(14) No. 2 rails will be accepted up to ten (10) per cent. of the whole order. Rails that possess any injurious defects, or which for any other cause are not suitable for the first quality, or No. 1 rails, shall be considered as No. 2 rails; provided, however, that rails which contain any physical defects which impair their strength shall be rejected. The ends of all No 2 rails shall be painted white in order to distinguish them. **No. 2 Rails.**

Respectfully submitted on behalf of the Committee,

W. R. WEBSTER,
Chairman.

EDGAR MARBURG,
Secretary.

[For Discussion of this report, see page 87.]

NOTE.—The specifications embodied in the above report were referred to letter-ballot of the Society by two-thirds vote at the Tenth Annual Meeting, and adopted by a vote of 125 affirmative and 18 negative, canvassed on August 26.

The standard length of finished rails was originally fixed at 30 ft. instead of 33 ft. by the Committee, on account of the then existing scarcity of cars, especially in the East, of suitable length for the shipment of longer rails. This condition having disappeared the Executive Committee, acting on a recommendation to that effect from Committee A and confirmed by the members of that Committee by letter-ballot without a dissenting vote, has authorized the adoption of the 33-ft. length in the Standard Specifications, since the change is one not affecting the quality of the product but dictated by practical considerations only; this action to be subject to the approval of the Society at the next annual meeting.

The Standard Specifications embodying this change and the corresponding modifications in paragraph (4) on Finishing Temperature, and paragraph (9) on Shorter Acceptable Lengths, follow in the succeeding pages.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR STEEL RAILS.

ADOPTED SEPTEMBER 1, 1907.

Process of Manufacture.

(1) (*a*) The entire process of manufacture and testing shall be in accordance with the best current practice, and special care shall be taken to conform to the following instructions:

(*b*) Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled or until the metal in the interior has time to solidify.

(*c*) No bled ingots shall be used.

(*d*) There shall be sheared from the end of the blooms formed from the top of the ingots not less than x* per cent., and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does.

(2) Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

Chemical Composition

	50 to 59 Pounds. Per cent.	60 to 69 Pounds. Per cent.	70 to 79 Pounds. Per cent.	80 to 89 Pounds. Per cent.	90 to 100 Pounds. Per cent.
Carbon....................	0.35-0.45	0.38-0.48	0.40-0.50	0.43-0.53	0.45-0.55
Phosphorus, shall not exceed	0.10	0.10	0.10	0.10	0.10
Silicon, shall not exceed.....	0.20	0.20	0.20	0.20	0.20
Manganese	0.70-1.00	0.70-1.00	0.75-1.05	0.80-1.10	0.80-1.10

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* The percentage of minimum discard in any case to be subject to agreement and it should be recognized that the higher this percentage the greater will be the cost.

(3) One drop test shall be made on a piece of rail not less than four feet and not more than six feet long, selected from every fifth blow of steel. The test shall be taken from the top of the ingot. The rail shall be placed head upwards on the supports, and the various sections shall be subjected to the following impact tests under a free falling weight: **Drop Test.**

	Weight of Rail. Pounds per Yard.	Height of Drop. Feet.
	45 to and including 55	15
More than	55 " 65	16
More than	65 " 75	17
More than	75 " 85	18
More than	85 " 100	19

If any rail break when subject to the drop test, two additional tests, taken from the top of the ingot, will be made of other rails from the same blow of steel, and if either of these latter tests fail, all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted.

(4) The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot-saws, for a 33-foot rail of 100 lb. section, of $7\frac{5}{16}$ inches, and $\frac{1}{16}$ inch less for each 5 lb. decrease of section. These allowances to be decreased at the rate of .01 inch for each second of time elapsed between the rail leaving the finishing rolls and being sawn. No artificial means of cooling the rails shall be used between the finishing pass and the hot-saws. **Finishing Temperature.**

(5) The drop testing machine shall have a tup of two thousand (2,000) pounds weight, the striking face of which shall have a radius of not more than five (5) inches, and the test rail shall be placed head upwards on solid supports three (3) feet apart. The anvil block shall weigh at least twenty thousand (20,000) pounds, and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made. **Drop Testing Machine.**

(6) The manufacturer shall furnish the inspector, daily, with carbon determinations for each blow, and a complete chemical analysis every twenty-four hours, representing the average of the **Chemical Analyses.**

other elements contained in the steel, for each day and night turn. These analyses shall be made on drillings taken from a small test ingot.

Weight Section.

(7) Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with paragraph (8) relative to specified weight. A variation in height of one-sixty-fourth ($\frac{1}{64}$) of an inch less, or one thirty-second ($\frac{1}{32}$) of an inch greater than the specified height, and one-sixteenth ($\frac{1}{16}$) inch in width will be permitted.

(8) The weight of the rails will be maintained as nearly as possible, after complying with paragraph (7) to that specified in contract. A variation of one-half ($\frac{1}{2}$) of one per cent. for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

Length.

(9) The standard length of rails shall be thirty-three (33) feet. Ten per cent. of the entire order will be accepted in shorter lengths, varying by even feet to twenty-seven (27) feet, and all No. 1 rails less than 33 feet shall be painted green on the end. A variation of one-fourth of an inch in length from that specified will be allowed.

(10) Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs.

Finish.

(11) *Straightening.*—Care must be taken in hot-straightening the rails, and it must result in their being left in such a condition that they shall not vary throughout their entire length more than 5 inches from a straight line in any direction, when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as second-quality rails and be so stamped.

The distance between supports of rails in the gagging press shall be not less than 42 inches.

Rails shall be straight in line and surface when finished—the straightening being done while cold—smooth on head, sawed square at ends, variation to be not more than $\frac{1}{32}$ inch, and, prior to shipment, shall have the burr occasioned by the saw cutting removed, and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds.

Branding. (12) The name of the maker, the weight of rail and the month and year of manufacture shall be rolled in raised letters on the side of the web, and the number of blow shall be plainly stamped on each rail where it will not subsequently be covered by the splice bars.

Inspection. (13) The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times when the contract is being filled, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with the terms of these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment.

No. 2 Rails. (14) No. 2 rails will be accepted up to ten (10) per cent. of the whole order. Rails that possess any injurious defects, or which for any other cause are not suitable for the first quality, or No. 1 rails, shall be considered as No. 2 rails; provided, however, that rails which contain any physical defects which impair their strength shall be rejected. The ends of all No 2 rails shall be painted white in order to distinguish them.

ON RAIL STEEL AS MANUFACTURED BY THE CONTINUOUS OPEN-HEARTH PROCESS.

BY BENJAMIN TALBOT.

As we have been rolling for some little time past heavy flat bottomed rails from steel made from phosphoric Cleveland pig iron by the continuous open-hearth process with which my name is connected, at one of our English works, I have been asked by Mr. Webster to submit a short paper dealing with the results obtained from such steel. We have not, of course, been able to submit any results relating to the life of the rails in actual service, owing to the short time that we have been manufacturing them, but I have obtained from the official of the works details of some specially severe tests some of these rails were subjected to, together with the ordinary mechanical and chemical tests of these charges, which will enable one to judge of the very tough nature of the steel obtained.

The continuous process is really only a modification of the open-hearth system of steel making, and the product obtained is absolutely open-hearth steel, so that we are not dealing with any untried product. From a metallurgical point of view the use of this process offers several advantages over the ordinary open-hearth process, which it is not here necessary to enter into. It will suffice to say that the essential advantages which the process offers are the production of very large outputs from a given unit of plant, coupled with a very high yield of steel ingots from a given weight of pig iron, as compared with ordinary open-hearth practice.

Steel rails have been made by the continuous process both from molten pig iron and also from Bessemerized metal fed into the steel furnace. In the latter case it is purely a question of the cost of Bessemerizing and small basic additions, as against the cost of a large quantity of oxidizing material otherwise required to convert the crude molten metal. Manifestly a 200-ton continuous steel furnace when fed with blown metal from the Bessemer converter will produce a very large output of ingots, probably some 3,000 tons per week or more. In either case the steel rail made is equally good, as a high carbon, low phosphorus product is obtained, and under such conditions four or five of these furnaces would keep an American steel rail mill busy.

The rails, of which details are given in Fig. 1,* were made from high phosphorus pig iron (about 2 per cent.) far more difficult to treat than the majority of American pig irons. If we had to treat a pig iron similar to that used in the acid Bessemer in America, containing about 0.1 per cent. phosphorus we should, without taking any pains to do so, lower this phosphorus to about 0.03 per cent. or thereabouts, which is obviously an excellent material for rail purposes, as the carbon can be varied at pleasure; that is, it is practically as easy to make .7 to .8 per cent. carbon steel as it is to make

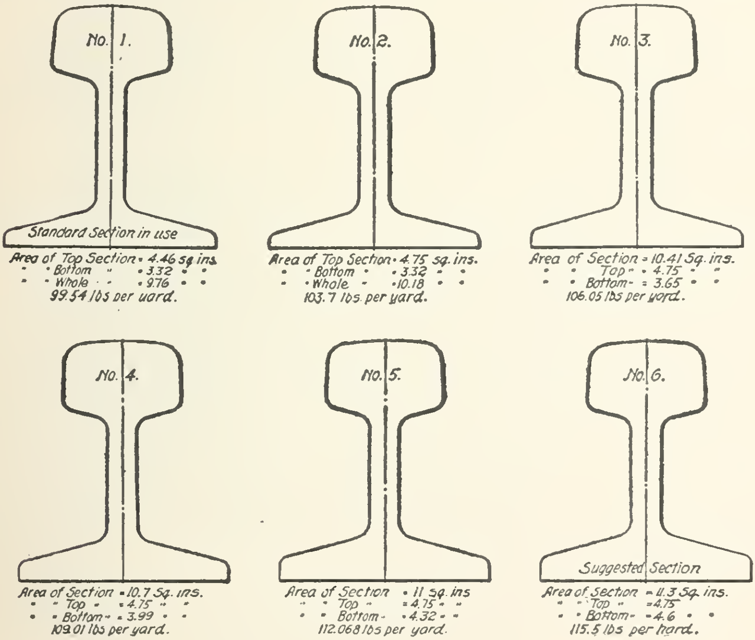

FIG. 1.

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* Acknowledgment is made to the *Railway and Engineering Review* for the cuts used in this paper.

.3 to .4 per cent. carbon steel. It is found also from practical experience that the steel from the continuous bath is somewhat less oxidized than steel from the ordinary open-hearth furnace; this is proven by the fact that a given weight of ferro-manganese will increase the manganese in the steel rather more in the case of the Talbot steel than it will in ordinary open-hearth steel, for which reason in practice we add rather less ferro than is required in other open-hearth furnace practice.

The treacherous nature of steel high in carbon manganese and phosphorus is too well known to need dwelling upon, and any increase in the carbon accentuates this danger. A point, however, which has not been so much dwelt upon is whether high carbon steel, even though low in phosphorus is not in some cases dangerous due to the fact that segregation will take place, sometimes to a very marked amount.

The statement has recently appeared in print that the Pennsylvania Railroad Company has specified that the open hearth rails which they propose to call for in future must have 0.8 to 0.9 per cent. carbon, for 90 to 100 pound rails with 0.03 per cent. phosphorus. Undoubtedly this steel should form a very excellent material for rail purposes, if it could be guaranteed that no segregation of the carbon would take place, whereby one part of the rail might become still higher in carbon, and so cause the material to become more brittle. It will be of interest to learn how such higher carbon rails behave in practice, and especially how they stand shock under low temperatures. Possibly rails with 0.75 carbon, 0.03 per cent. phosphorus, and manganese not above 0.7 per cent., will give the best results.

QUALITY OF MATERIAL.

We could not fill the requirements demanded by to-day's specifications with Bessemer steel made from such raw material as is available generally in the United States.

We append a schedule of tests giving the mechanical results also the analyses of the steel and molten pig from which such test was made. This steel is basic open-hearth made by the Talbot continuous process. From these figures it will be seen that these rails were subjected to a much more severe mechanical test than is ordinarily called for by engineers. One ton dropped once on to the head after the rail is placed on supports 3 feet 6 in. center to center is what is asked for. With regard to the drop tests in the above schedule; the first drop is with the head up; the rail is then reversed, and in each case came practically straight upon reversal.

Schedule of Tests
of Rail Steel Made in the Continuous Open Hearth Process.

No.	Carbon Req'd.	Analysis of Steel.					Tensile Tests.			Deflection on Drop of 1-Ton 30 Ft. 3'6" Centres									Remarks	Analysis of Pig from which steel was made		
		Car.	Sil.	Sul.	Phos.	Man	Tons per □"	Elong in 3"	Reduct	1st Blow	2nd	3rd	4th	5th	6th	7th	8th	9th		Sil.	Sul.	Phos
1	.55 to .65	.59	.019	.042	.037	.77	51.0	% 12.0	13.4	$3\frac{1}{4}''$		$3\frac{3}{16}''$		$3\frac{3}{8}''$					Twisted at 6th blow no fracture.	.89	.13	2.2
2	.40-.50	.49	.031	.046	.065	.94	52.6	11.0	9.7	3"		3"		3"		3"		$3\frac{1}{8}''$	Twisted at 9th " " "	.93	.09	2.3
3	40-.50	.49	.046	.04	.032	.92	49.7	12.5	11.3	$3\frac{3}{8}''$		$3\frac{1}{4}''$							Broke on 5th blow.	.84	.116	2.2
4	40-.50	.46	.046	.066	.026	.816	42.2	13.0	14.3	$3\frac{7}{8}''$		$3\frac{3}{8}''$							Twisted 3rd blow no fracture.	.93	.085	2.4
5	40-.50	43	.04	.071	.048	.756	40.8	18.0	18.7	$4\frac{1}{8}''$		4"							" " " " "	.70	.083	2.4
6	40-.50	.47	.037	.038	.04	.866	46.0	13.0	16.3	$3\frac{3}{4}''$		$3\frac{11}{16}''$		$3\frac{5}{8}''$		$3\frac{3}{16}''$			Twisted 7th blow no fracture.	1.17	.099	2.2
7	40-.50	.48	.031	.029	.039	.855	47.3	13.0	15.3	$3\frac{1}{2}''$									Broke 3rd Blow.	.79	.113	2.1
8	40-.50	.45	.05	.05	.061	.716	43.0	15.5	12.2	4"		$3\frac{7}{8}''$		$3\frac{7}{8}''$		$3\frac{5}{8}''$			Twisted at 7th no fracture	.79	.09	2.4
9	40-.50	.44	.035	.059	.036	.723	40.2	16.0	18.8	4"		$3\frac{3}{4}''$							" " 3rd " "	.75	.103	2.3

INCREASED WHEEL LOADS.

This can only be met by the introduction of a stronger and heavier rail. The tendency in designing tee rails in the past has all been in the direction of big heads, thin webs and flanges together with increased height. In the manufacture of such a rail it is almost impossible to avoid internal strains, set up in cooling on the hot bank. The duty of the rail designer is to design a rail which will cool straight when laid on the hot bank without cambering. This is only practically possible with a double headed rail (a rail with both heads of equal areas). In designing a flat bottom rail this condition should be approached as near as possible. Fig. 1 shows a set of sections, No. 1 being a fairly representative 100-pound rail. No. 6 is a suggested section with head and flange of equal area. This would be as near as it would be possible to approach the perfect design with tee rails, though a reduction in height might improve it. Nos. 2 to 5 are intermediate steps or compromises between what we are actually rolling and what we would suggest is the best section. How far would the railway engineer be prepared to go in this direction?

If the matter is carefully gone into, it will be demonstrated beyond any doubt that section No. 6 is a much stronger rail than is accounted for simply by the increase of weight, because with rail No. 1 great strains are already existing before any load is put on. Another beneficial direction to go in is the increase in the radii of the fillets which join web to flange and head respectively,

METHOD OF ROLLING.

In the formation of the grooves in the rolls much damage can be and often is done to the steel. With the object of increasing the product of a given mill the ingot is rolled off at one heat, with heavy reductions in each pass so as to reduce the number of passes and consequently the time taken in rolling. Our practice is to take large ingots and have a furnace between the cogging and finishing mills which has the effect of acting as an equalizer so that the blooms are delivered to the finishing mill at an even temperature right through, making the bar more easily shaped and the flange of the rail is sent out of the finishing groove at a temperature nearer to that of the head than has hitherto been possible. This does, no doubt, lessen the strains set up in cooling on the hot banks. Our practice is to increase the number of passes, decrease the amount of reduction per pass, and get the product by increased speed of the rolls and not by digging into and tearing the metal as is done in the case where too few passes and heavy drafts are adopted.

With regard to rolling temperature, we may say we roll a 100-pound rail in lengths which give, after crops are cut off, three lengths of 10 metres. The first length is cut within 15 to 20 seconds after leaving the finishing groove of the mill and on this we allow 7⅜ in. shrinkage. The next length is cut within 35 to 50 seconds from leaving groove, and here 7¼ in. is allowed. The third is within 60 to 80 seconds and 7 in. is allowed for shrinkage. Of course these allowances only apply to 100-pound rails, less allowance is made in lighter rails.

An interesting experiment may be tried n a tee rail, which has been finished and straightened. Take 6 or 8 feet of rail and place it on a planing machine and cut the head off the web at point where the web joins the head and both the head and bottom portion will spring out of a straight line sometimes to a very marked extent, thus showing that great internal strains are there. This is a condition that cannot be avoided by the manufacturer without some help from the rail designer.

As rails increase in weight the ingot from which they are rolled must also increase in size if sufficient work is put upon the rail. If high phosphorus has been permitted for smaller ingots rolled into lighter rails, the same average phosphorus should not be permitted in the larger ingot as greater segregation will occur.

[For Discussion of this paper, see page 87.]

MECHANICAL EXPERIENCES WITH LIMBER AND STIFF RAIL SECTIONS.

By P. H. Dudley.

I made a brief comparison of the mechanical properties of different sections in a preceding paper (Vol. V, p. 165), indicating that the stiffer rail sections could and would carry larger bending moments in distributing the wheel loads and generated wheel effects of the passing locomotives and cars, to the cross-ties, ballast and road bed, than the weaker sections they replaced. The early limber steel rail sections of $3\frac{3}{4}$, 4, $4\frac{1}{4}$, and even those of $4\frac{1}{2}$ inches in height, 50 to 65 lbs. per yard, distributed only a small percentage of the wheel effects to the wheel spacing, owing to their inadequate mechanical properties of stiffness and strength. The major portion of the wheel loads was concentrated in passing upon each cross-tie, which was cut rapidly in the rail seats, and disturbed the ballast and road bed. Rail sections when well fished act as continuous girders in the track and their efficiency increases with their mechanical properties in supporting the moving locomotives and cars. They receive their loads for distribution only through the wheel contacts of the wheel bases and their spacing limits the spans of the bending rails under the wheels, rather than that of the cross-ties.

The average generated kinetic effects of the rolling wheels on the limber-rails, doubled or trebled their static loads, and this enhanced the destructive work upon the track, augmented the train resistance, and cost of maintenance of motive power, rolling stock, and track. The static wheel loads of the locomotives and cars did not increase sensibly over those developed upon the iron rails, owing to the inability to maintain the tracks as smooth as desired even under the weights as then constructed.

The design of sections to carry the locomotive and car wheels $\frac{1}{2}$ to $1\frac{1}{2}$ inches higher above the cross-ties than the limber rails, by the use of only 25 to 50 per cent. more metal distributed to insure greater mechanical properties, for stiffer, stronger and smoother tracks, has enabled the wheel loads and expended tractive effort of the locomotives to more than double, upon the same road beds, in the past two decades. The first 100-ton passenger locomotive did not go into service until 1890, six years after the first 5-inch steel 80-lb. rails were laid in 1884. The strap iron rails in the thirties of 1800 were able to establish locomotion for light wheel loads only and failed when they reached two and three tons, owing to the generated wheel effects in rolling over the irregular surfaces of the rails and undulations of the track. The iron tee sections failed in the fifties and sixties, when the wheel loads had developed to 10,000 and 12,000 lbs. and the speeds to 30 or 40 miles per hour.

The physical properties of the metal were inadequate with its 1½ to 2 per cent. of included slag and imperfect welding of the bars composing the pile, to prevent crushing and laminating in the bearing surface under the rolling wheel loads. The utmost care in manufacture, either in England, Wales, or this country, could not make iron rails which would long endure heavy traffic. It was not carelessness, incompetence, nor dishonesty of the iron masters, as often alleged, but the fact that the work required of the metal exceeded its physical properties, and fatigue, failure, and fracture were the inevitable consequences after short service.

The operations of the railroads due to the commercial demands and development of transportation in thirty years after their inception, outgrew the physical properties to be obtained in iron rail sections as a metallurgical product in forms of value as engineering structures. The iron sections designed for larger mechanical properties as girders, for better track and smoother running of the locomotives and cars, from the larger bending moments carried and distributed with consequently greater intensity of the wheel contact pressures in the bearing surface, failed with greater rapidity than the former lower and weaker sections, under the same service. The heads of the tee rails were then made pear shaped to prevent breaking down under the wheel loads, but this did not check it. These were similar effects to those now experienced with piped and split rails under the heavy wheel loads. The causes of the failure of the metal, either in the iron or the steel rails, were due to inadequate physical properties in either case, though in the latter due more to the association of impurities, then Bessemer steel, when made from sound and solid ingots.

The failure of the iron rails to sustain the wheel loads in the bearing surface and their fracture as girders in distributing the loads to the cross-ties, was a subject of earnest solicitation to the railroad officials to find a substitute, and the Bessemer steel rails, fabricated from cast metal, were welcomed and extensively used. Their cost for many years limited them to light and flexible sections, which permitted a deep general depression under the moving wheel bases of the motive power and equipment, with decided specific deflections under the wheels and restricted increase of loads and development of the locomotives and cars as required for progress in transportation. The flexible rails carried and distributed only small bending moments, the intensities of the wheel contact pressures per square inch were also small, and moderate physical properties in the steel were ample for the service and rendered a slow rate of wear. The positive bending moments under the wheels did not reach 200,000 inch-pounds over 10 or 12 times daily, while the estimated intensities of the pressure per square inch in the bearing surface were under 80,000 lbs. from measurements of static loads.

To raise the bearing surface of the rails above the cross-ties ½ to 1½ inches higher than the limber sections, in the trackmen's surface, may seem small in the sense of dimensions, but when utilized in the design of sections of rails, with corresponding proportions of metal, the mechanical properties secured to carry and distribute heavier wheel loads increased their capacity 50, 100 to 200 per cent. in the different sections. The wheel loads and trains which have been developed and are running upon the stiffer rails have revolutionized transportation, so far as the capacities of the railroads are concerned. The gain due to the enhanced mechanical properties in the sections, saving destructive work to the cross-ties and road bed, can be secured only by a greater intensity of pressure under the wheel contacts, and increased work of the sections as girders to distribute their loads, *for which proper provision must be made in the physical properties and soundness of the metal used.*

The positive bending moments in the stiffer sections are 60 to 100 times daily over 600,000 inch-pounds, in some 100-lb. rails, under the heavier wheel loads and high-speed trains. The percentage of the wheel loads distributed to the wheel spacing is greater and the total bending moment produced by the wheel effects augments the wheel contact intensities two or three times their former amounts, in the light sections.

The depression of the stiffer rails from the trackmen's surface is from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch, compared to $\frac{5}{8}$ to 1 inch under the former light and limber rails; the maximum deflections in either case occur at or near the joints. The increased stiffness and strength of the sections—*mechanical properties by design*—render the track smoother, with firmer joints and less undulations, even when carrying the larger bending moments of the doubled and trebled wheel loads.

The percentage of generated destructive wheel effects on the limber rails has been reduced more than one-half by the stiffer and smoother rails, which has enabled the static and paying loads to be augmented in a greater ratio. The former 20,000 pound capacity freight cars have been replaced by those of 60,000, 80,000 and 100,000 pound, the 60,000 pound being the light car of to-day, while the 100,000 pound is the standard for mineral traffic. The freight train load has increased from 500 and 600 tons, to 3,000 and 4,000 tons, and the volume of traffic in like ratio. The axle loads under freight locomotives have risen from 25,000 to 50,000 pounds, with four pairs coupled instead of two, and in the passenger service 55,000 to 57,500 pounds are common for recent locomotives, which attain speeds of 80 miles per hour daily to maintain their schedules of 54 miles per hour including stops. *New York and Chicago,* 960 *miles apart in distance, reduces to* 18 *hours by train, on stiff rails.*

The expended tractive effort has increased from 500 to 1,200 or more horse power, a decided factor in augmenting the wheel contact pressures, bending moments, and consequent stresses in the rails as girders. The steel bridges installed with the limber rails for an expected life of a century, have been replaced by those of more than double capacity for wheel and train loads, to realize the benefits of the stiff rails to handle the unexpected development of traffic.

The experience with the early limber rails was that the quality for the light wheel loads was satisfactory, but their deficiencies were the small mechanical properties for the increasing wheel loads. Endurance shafts have been made from a number of those early rails which rendered 12 to 15 years service, and at 35,000 and 40,000 lbs. unit fiber stress they have sustained only from

600,000 to 3,000,000 rotations, excepting a single brand of steel in which the elastic limits were from 52,000 to 56,000 lbs. The ingots drawn into blooms under steam hammers, their unoxidized blow holes were welded and formed solid steel, as a rule, for subsequent rolling into rails. This important fact, with the limited work required of the metal to carry and sustain the light wheel loads, has misled many railroad officials and investigators as to the essential physical properties in sound steel which are required in combination with large mechanical properties in sections, for wear and as girders to sustain and carry the present wheel loads and high speed trains.

The distances between the producer and consumer in this country are so vast that over 30,000,000 tons of steel rails are required in the 220,000 miles of main tracks, nearly ten times the amount in Great Britain, and our steel plants must be commensurate in size and scope, and run at full capacity, for the 3,000,000 or more tons of yearly output demanded. The mills have been remodeled, then rebuilt from time to time, as conditions of manufacture changed, for greater output and the unit of production per unit of time for the limber sections has been multiplied several times for the stiffer and heavier sections.

It is legitimate and proper to save all time possible between each distinct step in the process of manufacture or the performance of mechanical work. Rapidity does not deteriorate quality until the essential time for a step in the process is unduly reduced, then enlargement of the plant for that process is required for combined quantity and quality. The Bessemer departments have not been enlarged proportionately to the other parts of the mill, but the converters have been driven faster, and after recarburizing the blown metal, the time for complete chemical reactions and escape of the slag has been reduced unconsciously before teeming of the ingots commenced. The reactions but partially complete themselves in the setting steel of the ingot, the slag, oxides, and gases are often entrained instead of eliminated.

The minute globules or particles of slag from the reactions caught in the columnar structure, also in the secondary zone of blow holes, with or without associated oxides, are important factors in the checking of the tender skin of the ingots in blooming, and the subsequent tearing of the flanges as their extreme edges must slip in the passes of the rolls. The percentage of second quality and condemned rails is increased by these conditions. The slag and occluded gases in connection with segregated metal are important factors in split heads of rails, which develop between the ends after a short or long period of service, depending upon the thickness of the metal in the bearing surface, over the entrained slag and occluded gases.

The paper already mentioned, Volume V, p. 168, stated:

> "The splitting of the head in the earlier rails was in nearly all cases traced directly to a pipe in the ingot. These conditions still exist, yet there are numerous instances in which the pipe did not develop in cooling, but does in service, in unsound metal for the central core of the steel as indicated in Figs. 1 and 2. Pieces break from the side of the head, in steel where so decided liquation has occurred in the ingot as to make two or more grades of steel in the head."

Continued examinations of numerous fractures of split heads, designated by the trackmen as "pipes," but which did not develop in cooling of the metal at the mill, but after short or long periods of service in the track, show that this type is the most frequent in the rapid increase of failures from so-called "piped rails" of recent manufacture. The shrinkage of the metal in cooling at best is only a minor factor as a contributing cause, neither are the split heads confined to the top rails from the ingots, but have been found in less numbers from all the rails of the ingot, where they have been lettered or numbered for subsequent identification.

A rolling of 10,000 tons of September, 1900, in the A. S. C. E. 80-lb. section, by July 1, 1906, 9.61 per cent. of the rails had been removed from the track for split heads. Subsequent rollings per year are showing split heads, though the percentage of removed rails is not yet as high, of the same brand. A rolling of 3,000 tons in September, 1903, from another mill, over one-fourth of the rails were removed in 1904, of which a large percentage are bad split heads, in connection with otherwise decidedly unsound metal.

Rails were taken from the track which indicated a split head had started to develop, and slag was found as a series of minute flattened longitudinal threads in the thin layer of metal in the bearing surface over the developed vertical check in the metal underneath, as illustrated in Fig. 1.* The slag located so near

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*Acknowledgment is made to the *Iron Age* for some of the cuts used in this paper.

the bearing surface is crushed by the constant rolling loads at what becomes subsequently the cusp of the curve of the upper detached metal from that underneath, and by repeated rolling loads shears and expands transversely, retaining each increment beyond its elastic limit, splitting the segregated metal of the head underneath. Were we to request our mechanical engineers to supply mechanism to split the rail heads they would be unable to furnish in so few parts acccumulators of such destructive forces.

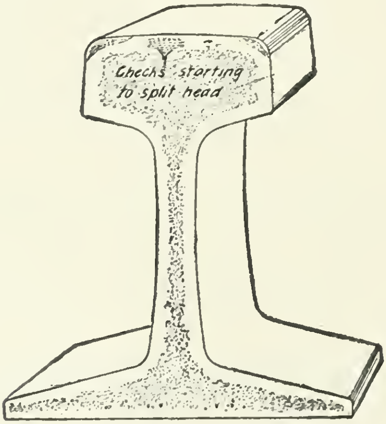

FIG. 1.—This shows the laminæ of metal in the bearing surface, with slag inclusions which crushed under the wheel loads. The cusp formed at the point of weakest resistance, a slag inclusion of larger dimensions—then by shearing, the checks develop upward and tranversely under the rolling loads, separating and expanding the upper layer of metal in the bearing surface from the core of more or less fragile segregated metal underneath, thus starting the vertical check.

The illustration in Fig. 2 shows the segregated metal in the bearing surfaces as expanded sufficiently to complete the check from the upper to the lower portion of the head. The cusp point by the expanding of the metal sidewise is now located slightly beyond the first check. The under side of the expanded metal shows the shearing and stretching from the repetitions of the numerous wheel loads in passing over the rail.

The composition of steel rails shown in Figs. 3 and 4 is carbon

0.55 to 0.60, manganese 1.00 to 1.20, silicon 0.10 to 0.15, phosphorus not to exceed 0.06 and sulphur not to exceed 0.07. The copper, which was not specified, averaged in those rails 0.7 to 0.8. The iron was remelted in cupolas, and the temperature of the heat in the converter regulated by 1,800 to 2,000 lbs. of scrap, charged before the receipt of the molten iron. The bath was recarburized in the converter and the metal poled in the ladle by thrusting in a green wood pole. It was 1 or 2 minutes before teeming of the ingots commenced, the ladle nozzle was $1\frac{1}{8}$ in. in diameter, and 6 or 7 minutes consumed in pouring the 10-ton heat in five ingots,

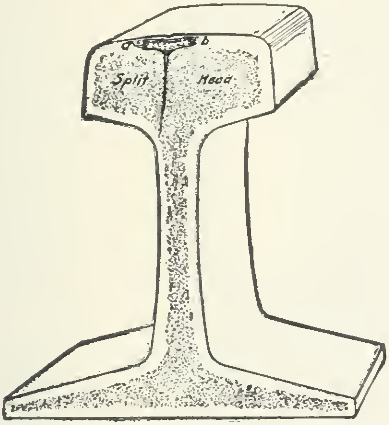

FIG. 2.—Shows the vertical check developed until the head is split. The layer of metal in the bearing surface unchecked vertically at either *a* or *b*, the split widens, as it expands transversely—for the metal underneath becomes the anvil for the endless succession of blows delivered by the rolling wheels—until the total is reached and the piece detached.

15 x 15 inches square on the base and of sufficient length for three 30-foot rails. The ingots were charged into horizontal furnaces, rolled direct in 13 passes, $3\frac{1}{2}$ minutes from first blooming to the finishing pass. The hot rails were sawed $\frac{1}{2}$ inch longer than for present practice, and spaced six inches apart on the hot beds, and turned after recalescence of the head.

Five hundred thousand tons of rails of that character were made, with the exception that for the 100-lb. sections the carbon was raised 5 to 10 points and the manganese about 10 points

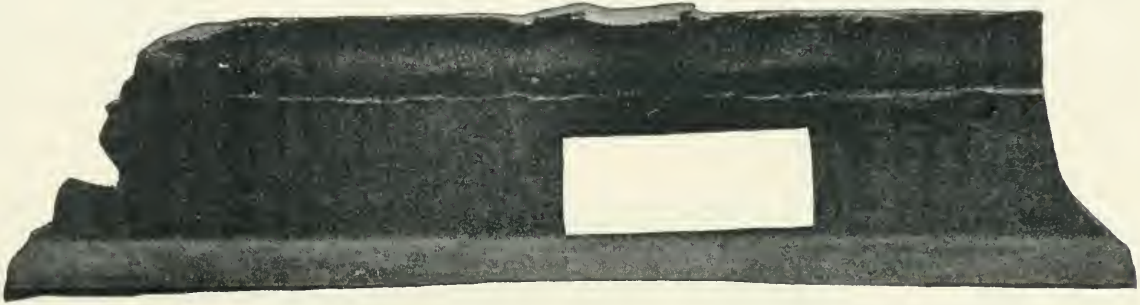

FIG. 3.—Side view of rail from which one side of the head has split, after 14 years' service. $5\frac{1}{8}$ inch 80 lb. rail, rolled 1892, laid same year, in Track No. 1, Main Line, N. Y. C. & H. R. R. R., west of Savannah, relaid in Track No. 4, 1903. Side of head detached and section broke as a girder, February 24, 1907. Head lost in height $\frac{1}{8}$ of an inch, for estimated 144 million tons, high speed trains, and 72 million tons of heavy freight traffic. Traces of slag in bearing surface but none on side walls of fracture.

FIG. 4.—Full size piece split from head of rail. 5⅛ inch 80 lb., rolled 1892, laid same year, broke February, 1907. Traces of slag in bearing surface, and the lines visible between separated metal underneath. See Fig. 5. Trace of minute seam in center of head.

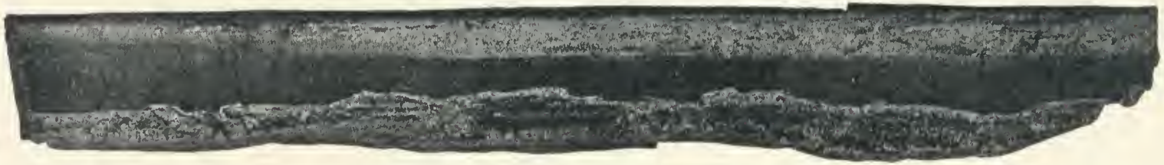

FIG. 5.—Top view of No. 4. The irregular line of fracture in the bearing surface, and the bruised surfaces of the lower plane of separated metal of the central core of the head, are well defined. The dark part of the bearing surface is the black streak in the rail, which indicates to the trackmen a split head is developing.

higher than for the 80-lb. rails. To date only 18 specimens are known to have developed what may be termed split heads, or "piped rails," as generally understood by the latter term. The rails from the ingots were lettered A for the top rail, B for the second rail, and C for the third. These letters can be found in the tracks, and, as would be expected, the A rails have a larger percentage of impurities than the B or C rails. They wear faster, developing more surface defects, and at several points upon the road, under heavy traffic, after 10 and 12 years' service, have become practically worn out for main line traffic, while the B and C rails are still good. I do not wish to convey the impression that no more split heads will occur in these rails. As the bearing surface becomes worn down from year to year, a number of heads will probably split, from the causes already indicated.

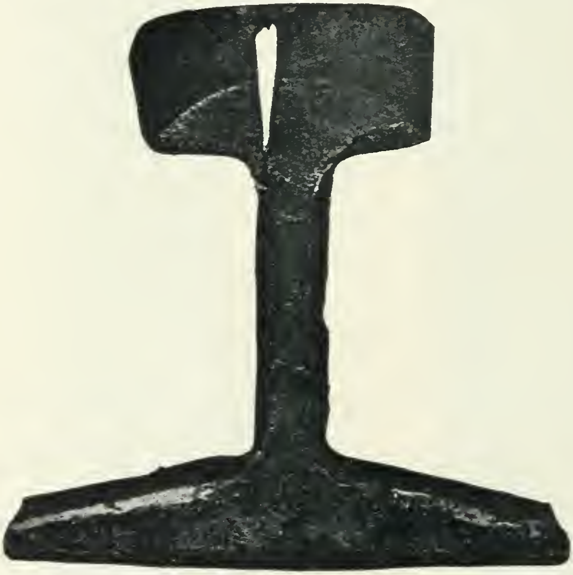

Fig. 6.—End view of split head, 90 lb., A. S. C. E., section, C., C., C. & St. L. Ry. Heat No. 44,011, rolled August, 1905, laid September, 1905, removed July 27, 1906.

It should be stated in reference to the defective rails that many times the minute quantities of slag in the bearing surface, without a larger blow hole in the secondary zone, do not always produce a split head, but the surface wearing away the metal flows laterally from the bearing surface, without splitting the rail head. It is also well known that the rail head composed of steel of a high degree of porosity, or slag inclusions, the metal will flow sidewise to the outer edge, without making a split head.

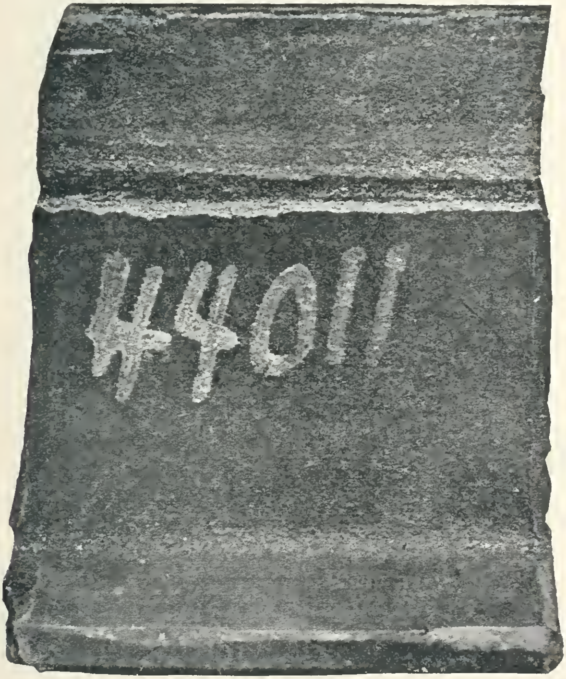

FIG. 7.—Side view of same rail as No. 6. Segregated metal, but not the slightest trace of a pipe. 7 minute threads of slag were counted in the thin layer of separated metal of the bearing surface.

The rails of the composition above mentioned, as girders have rendered excellent service, rarely breaking in extreme cold weather.

The explanations in reference to Fig. 4 also apply to Fig. 5, as part of the same rail. The pieces of rails in Figs. 6 and 7 illustrate split heads from the breaking of a thinner layer of metal in the bearing surface, than that in Figs. 3, 4 and 5, the rail failing after 11 months of service. The ingots were teemed with a 3-inch nozzle.

My records show as a general observation that rails rolled in August and September, when there is so much humidity in the air, have developed split heads in greater numbers than those rolled during the winter season. The moisture per cubic foot of air in August and September often is as high as 5 or 6 grains, while it may not be one-half of that amount during the winter weather.

The use of refrigerated air, in which the moisture was reduced to a low limit, would be preferable for use in the Bessemer converters. Each ton of metal converted requires approximately about 0.6 of a ton of air to be blown through it and with a large percentage of moisture it effects the physical properties of the metal by a greater inclusion of gases. The practice of many mills, with direct metal, to use a jet of steam to regulate the temperature of the blowing metal in lieu of scrap, is decidedly objectionable, and injurious to the resulting product.

The piece of rail represented in Fig. 8 was broken from the head of a piped rail. The side walls of the pipe which had been closed in rolling were oxidized in the soaking pits. The failure of the rail however was due to the spreading of the metal in the bearing surface as already indicated. Seams from inclusions of slag are visible on the under side of the head. This type of split heads from a well-defined pipe was common in the early steel rails in which the ingots were cooled before being charged into the furnace.

The percentage of split heads can be decreased by giving the metal in the ladle more time for the slag, oxides and gases to escape before teeming, than is usual in the present rapid practice. It needs only a return to the older methods of allowing more time after recarburizing for the chemical reactions, escape of the slag, oxides, and other impurities to improve the soundness of the ingots. The large ingots, those of 20 x 21 inches or 24 x 27 inches on the base, and comparatively short, the steel can be made to set sounder and better than in the smaller bases and proportionately longer ingots. The escape of the slag must be in the ladle before teeming to prevent it being entrained in the skin of the ingot. The segregation in the larger ingots with the longer time of cooling seems to be more pronounced, but unless layers of slag are found in the exterior portions of the head of the rail, split heads have not so far been as numerous in that type of ingot as in the relatively smaller base but longer ingot. The number of seconds and condemned rails is also proportionately less.

Figs. 8 and 9 illustrate also a type of fracture where pieces of the rail from 8 to 20 inches in length break from the sides of the head. These are distinct pocket pipes of gas, slag inclusions, or minute threads of entrained slag in the metal, the latter are most numerous, particularly in the bearing surface of the head. The crushing and flowing metal under the wheel treads, shears or splits off the piece, which then becomes detached from the head of the rail.

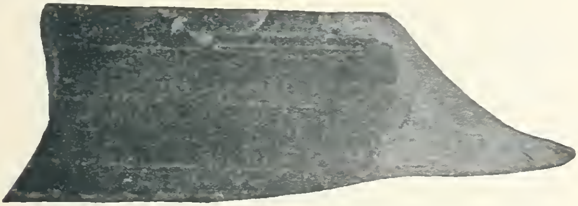

FIG. 8.—Side view, full size, from side of $5\frac{1}{8}$ inch 80 lb. rail, rolled 1901, broken March 15, 1907. This was a piped rail from a well-defined cavity in the ingot, the side walls oxidized in heating. The piece was detached by the spreading of the metal in the bearing surface.

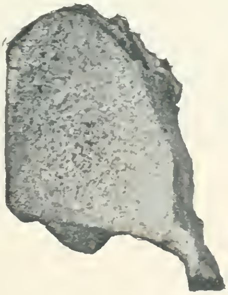

FIG. 9.—End view of piece broken from side of head of $5\frac{1}{8}$ inch 80 lb. rail, rolled 1901, and laid in tangent, west of Schenectady, Track No. 2. Broke March 15, 1907. Pocket pipe. This is the end of the longitudinal piece shown in Fig. 8.

Figs. 10 and 11 illustrate split heads in which the layer of metal in the bearing surface over the segregated steel is thin, not to exceed $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in thickness. Such rails fail within six months or a year after being placed in the track, under heavy traffic. The percentage of carbon in the bearing surface of the split heads is usually 10 to 15 points below the normal composition of the rail, while the segregated metal in the interior is usually 15 to 20 points above. The phosphorus, of metal of about 0.06, will show from 0.07 to 0.08 in the segregated metal, while phosphorus of about 0.10 for the rail in the segregated metal will often show 0.12 to 0.15.

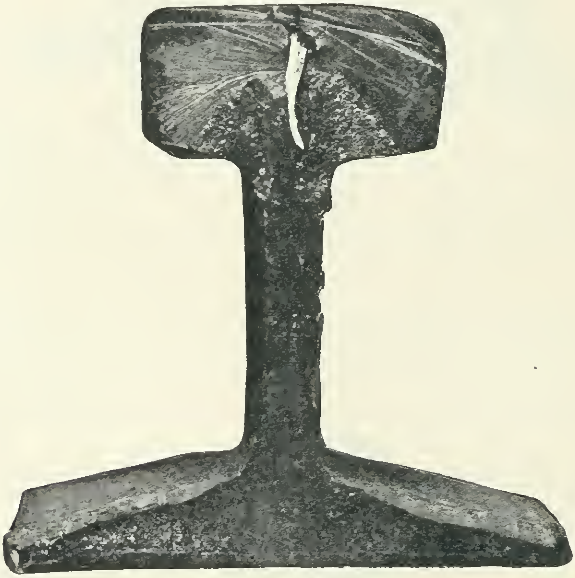

FIG. 10.—Transverse view of split head, No. 27, C., C., C. & St. L. Ry., 90 lb., A. S. C. E. Carnegie O. W., rolled August, 1905, laid 10th of same month and removed March 11, 1906. Heat No. 48,568.

The pieces of the rail illustrated by Figs. 12, 13 and 14 are of especial interest from the fact, that the metal was of sufficient soundness and strength to sustain a traffic of over 350 million tons. *The rail was from the top of the ingot, and while it shows distinct segregation, was comparatively strong, sound metal.* The phosphorus in the bath was under 0.06 though slightly higher in this segregated metal. The carbon ranged from 0.60 to 0.65 and the rail was comparatively hard, tough metal. The chemical analysis from one piece of the rail was:

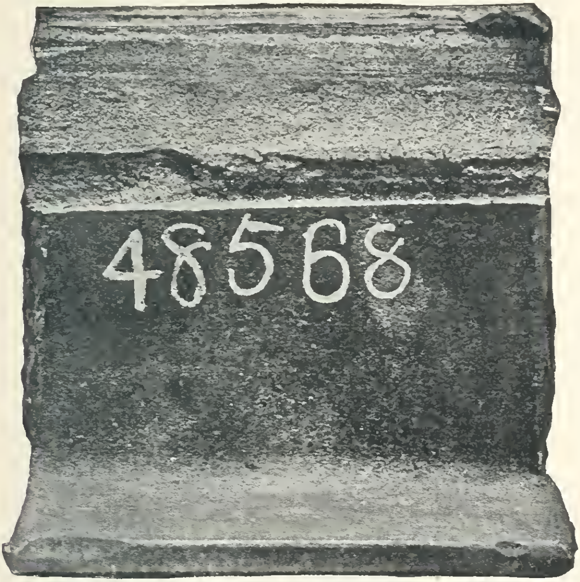

FIG. 11.—Side view showing split head No. 27, C., C., C. & St. L. Ry. Transverse view is shown in Fig. 10. In the thin layer of the metal in the bearing surface 14 threads of slag have been counted in the thickness of less than $\frac{1}{16}$ inch. This view shows segregated metal with a trace of seam $\frac{1}{2}$ inch below the top of the head. The uneven line of the separated metal in the central core about $\frac{1}{8}$ inch from the upper part of the bearing surface is plainly shown, also the effect of expanding the metal of the bearing surface immediately above.

No. 1. $\frac{1}{4}$-inch under Bearing Surface:
Carbon 0.586 Mn. 0.88 Si. 0.099 Sul. 0.033 P. 0.035

No. 2. Side of Head:
Carbon 0.517 Mn. 0.88 Si. 0.099 Sul. 0.032 P. 0.032

No. 3. $\frac{1}{2}$ inch below and to the right of center of Head:
Carbon 0.834 Mn. 0.98 Si. 0.087 Sul. 0.066 P. 0.073

FIG. 12.—This shows a longitudinal section of split head, 100 lb. rail, New York Central Lines. Rail rolled by the Lackawanna Iron and Steel Co., Scranton, May, 1893, laid the following June in Grand Central Yard on Inbound Main, and removed June 12, 1907. The rail has been used in each side of the Inbound Main and was removed from the track for the purpose of tracing the split in the head before the surfaces were completely oxidized. Minute layers of slag have been noticed in the bearing surface, just visible under magnification of 25 diameters. Seams which have developed in the bearing surface after so many years service are also noticed in Figs. 13 and 14 which are parts of the same rail. The traffic which has passed over the rail is over 350 million tons.

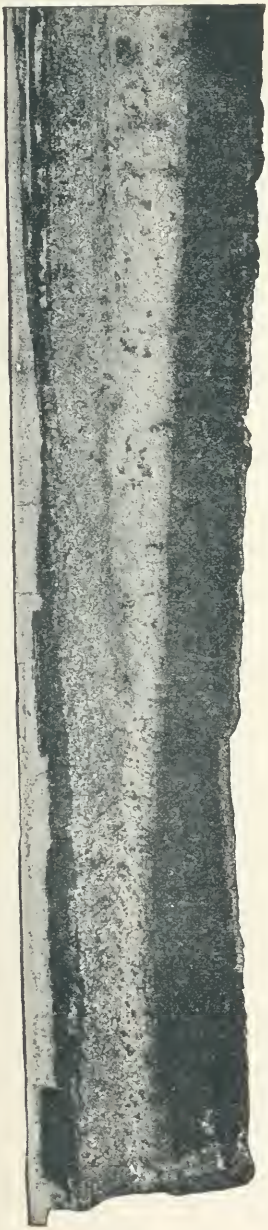

FIG. 13.—This shows definite traces of the segregated metal, but without seams, except those immediately in the bearing surface. The split had extended 10 feet in length in the rail in the direction of the traffic. The lower dark surface in the section is from oxidation from the openings below the head of the rail. The minute curved lines as the fracture proceeded may be noticed in this specimen. The metal while segregated is comparatively sound. This can be understood from the fact that it has carried such a large tonnage in its long period of service. The rail has lost about $\frac{1}{8}$ of an inch in height.

The carbons by color test. The apparent differences in sulphur and phosphorus are marked, and are under investigation.

The flow of the metal was slow and required an enormous tonnage to start the rail to split under the developed checks in the bearing surface. To detach the pieces from the rail after being taken from the track required many blows from the spike maul. Thin steel wedges were driven into the checks from the end, and short pieces of about 8 inches in length would break from the side without extending the split a greater length in the head of the rail. The inclusions of slag are not constant in quantity for the entire surface of the rail, and were found to be located in spots a few inches apart. The sounder metal required a long time for the wheel loads to split from one series of inclusions of slag to the next.

Several other rails have been examined since June 21st, and the slag in the bearing surface was sufficient to permit the metal to flow and expand sidewise and start a check in what would otherwise be metal which would sustain the traffic without splitting of the head or deformation of the bearing surface of the rail. Rails under Gantry cranes, which have large static wheel loads but a slow velocity, will cause the metal in the bearing surface, with slag inclusions, to flow and split the rail heads as well as trains.

The heavy wheel loads of the present service must be expected to affect the metal in the bearing surface more quickly than was the case with the lighter loads on the limber rails. It is quality and sound metal that is required in any form of section at the present day, to sustain the high-speed trains, heavy wheel loads, and large expenditure of tractive effort.

The 75, 80 and 100 lb. stiffer rails, which were made in 0.06 phosphorus, 0.50 to 0.65 in carbon, have sustained the present heavy traffic for a number of years in the bearing surface without undue wear, and have not broken as girders, under the high-speed trains, heavy axle loads, and the large expenditure of tractive effort. The failure by the breaking down of the rail heads has been traced in all cases to unsound metal, rather than its distribution in the section. The failure of recent rolled rails in the heavy sections, either as to rapid wear or breaking of the heads, or the entire section, seems to be due to inadequate physical properties in combination with unsound metal. To sustain the heavy service and with the large output demanded, it is more difficult to

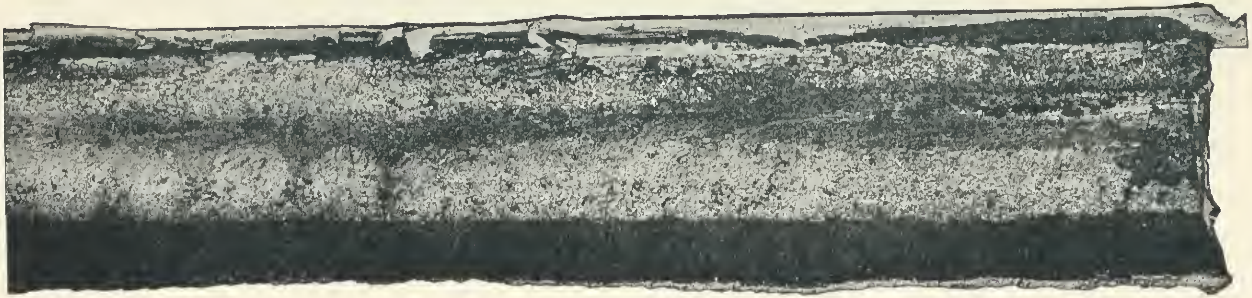

FIG. 14.—A part cut from Fig. 13. Figs. 12, 13 and 14, form a piece 2 feet in length from the top of the same rail. 5 feet and 8 inches along the top of the rail, the segregated metal included for 2 inches in depth about 8 inches of the length of the web, the split crossing to the opposite side of the head.

make a rail owing to the lack of time for the necessary steps in the process rather than that of deficiency in the processes themselves, except as to the high phosphorus and sulphur. The high phosphorus, even with low carbons and cold rolling, makes a metal of greater fragility than was produced with the lower phosphorus and higher carbons when rolled even at the higher temperatures of the preceding decade.

Compression of the ingots would check the segregation of the metalloids in those of large dimensions, and the discard required for sound metal would be small. The composition of the metal for the rail can be an alloy, and a range in physical properties secured for wear, and as girders of greater toughness, for shocks in zero or lower temperatures.

The metallurgical problem is one limited by cost rather than confined to a single metal as formerly the case with iron rails. Progress in transportation will not be limited by specifications but will meet the commercial demands with larger factors of safety for the future.

[For Discussion of this paper, see page 87.]

DOES THE REMOVAL OF SULPHUR AND PHOSPHORUS LESSEN THE SEGREGATION OF CARBON?

BY HENRY M. HOWE.

If relative freedom from phosphorus and sulphur should lessen the segregation of carbon, this fact would increase the value of the thorough dephosphorizing and desulphurizing, which certain electrical processes, such as the Heroult, bring about.

We often think of segregation only as concentrating the sulphur and phosphorus harmfully in the upper part of the axis of the ingot; indeed, in case of low carbon steel this is its chief reproach. But in case of high-carbon steel, segregation does the further harm of giving great irregularity of carbon content. If these electrical refining processes not only expel sulphur and phosphorus, but thereby prevent or lessen the segregation of carbon, this is so much to their good.

In order to answer this question I have examined all the available cases of segregation, about one hundred in number, and I give the results in Appendices I, II, and III and the accompanying tables and diagrams.

Briefly, the evidence answers "No" to our question. In other words, it raises a strong presumption against the belief that either low sulphur content or low phosphorus content tends to restrain the segregation of carbon, and suggests rather that they have the opposite effect of aggravating that segregation. We can readily understand that freedom from sulphur should do this by leading to "liveliness" which in turn seems to favor segregation. The less sulphur, the more lively the steel; the more lively, the more segregation.

Those parts of this paper which refer to the influence of phosphorus are taken with slight changes from my report on this subject to W. R. Walker, Esq., Assistant to the President of the United States Steel Corporation; and I thank him sincerely for his generous permission to publish them.

APPENDIX I.—PLAN OF THE TABLES AND DIAGRAMS.

In the tables are given (1) the average sulphur or phosphorus as the case may be, (2) the average carbon A; (3) the maximum carbon B; and (4) the excess of the maximum carbon over that average in percentage of the average, or $\frac{B-A}{A} \times 100$. For convenience I give the sulphur, phosphorus, and carbon to only two places of decimals in the tables, though the diagrams follow the third place whenever this is known.

The ladle test, if known, is taken as the average. When it is not known, I calculate the average when the data permit me to with any approach to accuracy. When they do not, as is the case with certain rails, I take the outside of the rail as the nearest available approximation to the average.

I have rejected all cases in which the reported segregate is clearly not the segregate, for instance, all those in which it has less carbon than the average, because it is now clear that the segregation of carbon leads to an enrichment, not an impoverishment, of the last freezing part.

This has led me to reject many cases of rails reported by Mr. Robert Forsyth, I have rejected many of the cases reported by Mr. H. H. Campbell in his admirable book, because in these he took no drillings from the upper 25 per cent. of the length of the ingot, which would be very likely to contain the segregate. This without questioning the propriety of his course for the purpose which he had in mind.

In the diagrams the degree of segregation of carbon is represented by vertical distances, and the average percentage of sulphur or phosphorus by horizontal ones, using special signs, which are explained in the legends, to indicate the source of the information, the kind of object, the size of the ingots, and in case of the Talbot ingots, whether they are made with or without aluminum.

The center of each circle, cross, etc., lies at the point which its case represents.

APPENDIX II.—THE EVIDENCE CONCERNING SULPHUR CONSIDERED.

Our first impression, on examining Diagram I, is that low sulphur-content, instead of restraining, rather aggravates segregation, because the highest points, or those of the greatest segregation of carbon, lie at the left of the diagram, where the sulphur content is the lowest, and because there is on the whole something of a downward slope as we pass from left to right. Further, when we come

INFLUENCE OF SULPHUR ON SEGREGATION OF CARBON.

Segregation of carbon, or excess of richest point, B, over average, A; measured in percentage of that average, or $\frac{B-A}{A} \times 100$.

No.	Average Sulphur.	Carbon.			Object.	Size, inches.	Authority.
		Average A.	Maximum B.	$\frac{B-A}{A} \times 100$ per cent.			
1	trace	.85	1.02	20	Large bar	......	Metcalf.
2	.02	.39	.44	14	Rail	......	Jüptner.
3	.02	.29	.50	71	Rail	......	Jüptner.
4	.02	.35	.68	94	Rail	......	Jüptner.
5	.02	.15	.18	20	Ingot	13 ton	Acker.
6	.02	.37	.77	108	Ingot	Large	U. S. A.
7	.02	.23	.36	57	Ingot	16x18	U. S. A.
8	.02	.19	.32	68	Ingot	12x26	Huston.
9	.02	.09	.10	11	Ingot	13x13	Cheever.
10	.02	.12	.18	47	Ingot	16x18	U. S. A.
11	.03	.37	.92	149	Ingot	3 x39	Stubbs.
12	.03	.41	.53	28	Rail	......	Jüptner.
13	.03	.99	1.90	92	Ingot	16x18	U. S. A.
14	.03	.28	.53	89	Ingot	10x10	Pourcel.
15	.03	.33	.45	34	Rail	......	Forsyth.
16	.03	.17	.19	11	Ingot	10x10	Campbell
17	.03	.12	.16	39	Plate	......	Eccles.
18	.03	.26	1.11	327	Ingot	43x79	Colby.
19	.03	.51	.75	47	Ingot	15x15	Colby.
20	.03	.40	.48	21	Rail	......	Jüptner.
21	.04	.23	.38	65	Ingot	15x22	Huston.
22	.04	.23	.40	74	Ingot	15x22	Huston.
23	.04	.26	.65	155	Ingot	43x79	Colby.
24	.04	.10	.20	111	Plate	......	Parker.
25	.04	24	.86	258	Ingot	30 dia.	Hogg.
26	.04	.30	.39	31	Rail	......	Forsyth.
27	.04	.42	.42	0	Ingot	13x13	Snelus.
28	.04	.36	.50	40	Rail	......	Jüptner.

No.	Average Sulphur.	Carbon.			Object.	Size, inches.	Authority.
		Average A.	Maximum B.	$\frac{B-A}{A} \times 100$ per cent.			
29	.04	.39	.57	46	Rail	......	Andrews.
30	.04	.12	.14	17	Plate	......	Eccles.
31	.04	.24	.31	29	Rail	......	Forsyth.
32	.04	.19	.21	11	Ingot	17x21	Snelus.
33	.05	.25	.27	11	Rail	......	Forsyth.
34	.05	.19	.38	100	Ingot	30x34	Huston.
35	.05	.44	.77	75	Ingot	19x19	Snelus.
36	.05	.24	.32	35	Rail	......	Forsyth.
37	.05	.39	.54	39	Rail	......	Andrews.
38	.05	.37	.54	48	Rail	......	Andrews.
39	.05	.42	.56	35	Rail	......	Andrews.
40	.05	.30	.36	22	Ingot	10x10	Campbell.
41	.05	.38	.43	12	Rail	......	Forsyth.
42	.05	.15	.24	60	Plate	......	Eccles.
43	.06	.57	.70	23	Ingot	12x12	Stevenson.
44	.06	.62	.83	35	Ingot	19x19	U. S. A.
45	.06	.39	.51	33	Rail	......	Forsyth.
46	.06	.44	.60	36	Rail	......	Andrews.
47	.06	.43	.60	40	Rail	......	Andrews.
48	.06	.47	.62	32	Rail	......	Andrews.
49	.06	.47	.66	40	Rail	......	Andrews.
50	.06	.38	.95	150	Ingot	18x22	Talbot.
51	.06	.38	.48	26	Ingot	18x22	Talbot.
52	.06	.38	.60	58	Ingot	18x22	Talbot.
53	.06	.38	.53	40	Ingot	18x22	Talbot.
54	.06	.50	.71	42	Ingot	20x24	Talbot.
55	.06	.50	.75	50	Ingot	20x24	Talbot.
56	.06	.50	.80	60	Ingot	20x24	Talbot.
57	.06	.43	.56	31	Rail	......	Andrews.
58	.06	.89	1.11	25	Ingot	15x15	U. S. A.
59	.07	.42	.60	43	Rail	......	Andrews.
60	.07	.43	.74	72	Ingot	13x16	Talbot.
61	.07	.43	.67	56	Ingot	20x24	Talbot.
62	.07	.44	.67	52	Rail	......	Andrews.
63	.07	.12	.25	114	Ingot	20x24	Talbot.
64	.07	.43	.61	42	Rail	......	Andrews.
65	.07	.24	.68	183	Ingot	15,400 lbs	Reuss.
66	.08	.45	.58	29	Rail	......	Andrews.
67	.08	.49	.70	43	Rail	......	Andrews.
68	.08	.27	.41	52	Rail	......	....
69	.08	.45	.66	47	Rail	......	Andrews.
70	.09	.37	.37	2	Rail	......	Forsyth.
71	.09	.49	.56	14	Rail	......	Andrews.
72	.09	.40	.48	20	Rail	......	Andrews.
73	.11	.11	.16	48	Plate	......	Eccles.
74	.11	.25	.30	20	Rail	......	Forsyth.
75	.11	.43	.60	38	Rail	......	Andrews.
76	.13	.67	.74	10	Rail	......	Forsyth.
77	.15	.69	.87	26	Rail	......	Forsyth.

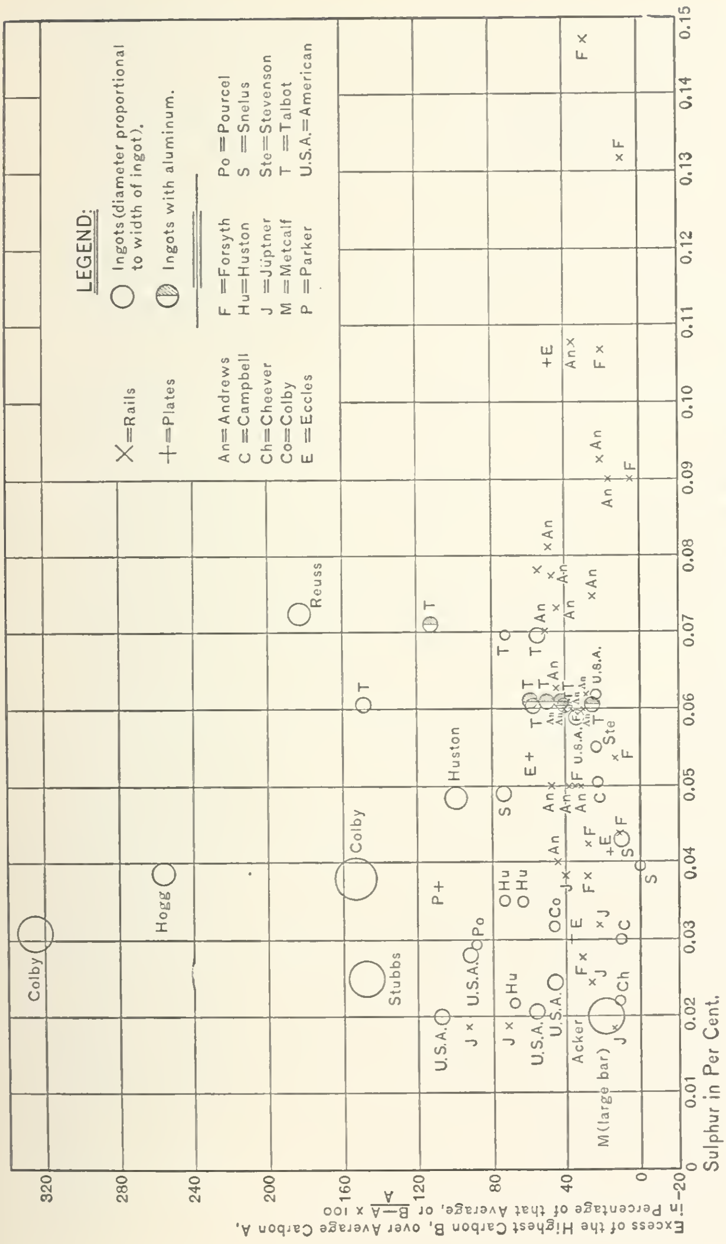

DIAGRAM I.—Influence of Sulphur on the Segregation of Carbon.

to examine these cases in detail, we find such facts as the following:

In all the cases in which the segregation of carbon execeds	The sulphur content is under
183. per cent.	0.04 per cent.
52. "	0.08 "
48. "	0.105 "

These facts certainly raise a presumption, at the first glance, against the belief that low-sulphur content restrains segregation; and we next consider whether any allowances which we can make should suffice to overcome this presumption.

We at once make a certain allowance as regards the four very large ingots represented in the upper left hand part of the diagram, the two Colby ones, and those of Hogg and Stubbs. The very large size of these ingots in and by itself should increase their segregation, so that their very great segregation may be due, not to their low sulphur-content but to their great size. The great segregation of the Hogg ingot may be due further to the exceptional skill and intelligence with which Mr. Hogg sought the richest of the segregate. But, even if we exclude these four cases completely, there still remains a decided downward slope as we pass from left to right.

Beyond this, we should make a certain allowance for the imperfection of our evidence. Be it remembered that no one of these cases gives the very richest of the segregate, which indeed is at most a group of but a few molecules. Even if our drillings were so taken as to include this very richest spot, in order that they should be of sufficient quantity for chemical analysis the richest of the segregate would be enormously diluted by the surrounding less rich material cut out with it in drilling.

But the drillings are hardly ever taken in such a way as to seek properly for the richest of the segregate. So far as I remember, Mr. Hogg* alone has sought this properly, by taking the whole of the axial matter in the segregated part of the ingot, and analyzing successive small parts of it. In general there has been no attempt to run down the richest spot, so that while the reported richest spot from one ingot may lie quite close to the true richest spot, that from another ingot may lie many inches from it.

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* "On Segregation," *Journal of the Society of Chemical Industry*, March 31, 1893, p. 4 of reprint.

Still farther, the degree of segregation is affected by other variables, such as the casting temperature, the rapidity of cooling, the slowness of casting, and most of all the quietness of the molten metal. But even after taking all these considerations into account, it is still naturally to be expected that plotting so large a number of cases as are here given should bring out some clear indication of the anti-segregation effect of low sulphur-content if such an effect really existed. The fact that the diagram instead of showing such indication suggests rather the opposite, raises a strong presumption against the supposed anti-segregation effect of low sulphur-content.

Now that we have gone as far as this, we may peep a little farther and ask, "Can it be that low sulphur-content actually favors segregation?" The evidence on its face certainly suggests this belief, and perhaps as strongly as could be expected in view of the necessary inaccuracy of sampling, and of the many other variables at work, such as ingot size, casting temperature, and quietness of steel.

We naturally ask ourselves whether there is any reason to expect such a law, and on reflection we find such a reason close at hand. It has been observed that steel, at least acid Bessemer steel, when very low in sulphur is wild and boils badly in the molds, and many steel makers throw a little of either pyrite or brimstone into any steel which is not quiet enough. In short, sulphur seems to have an influence like that of aluminum, quieting the steel, and thereby it might well restrain segregation in the way in which, as Mr. Stead has pointed out, aluminum does this very thing. In quiet steel the solidification is rather of the landlocking than of the onion type. Long columnar crystals shoot out from the walls of the ingot, and landlock much of the molten metal between them, thus restraining the centripetal concentration which is the essence of segregation. I believe that the reason why quietness has this effect is that it leads to surfusion. The metal actually remains molten below its normal freezing point, so that when freezing once sets in, it throws long crystals shooting out into the interior.

In short, we find a strong presumption against the belief that low sulphur-content restrains segregation of carbon, and indeed a suggestion that it aggravates that segregation. Beyond this, we find a reason, in the reported quieting effect of sulphur, why it should have this specific effect.

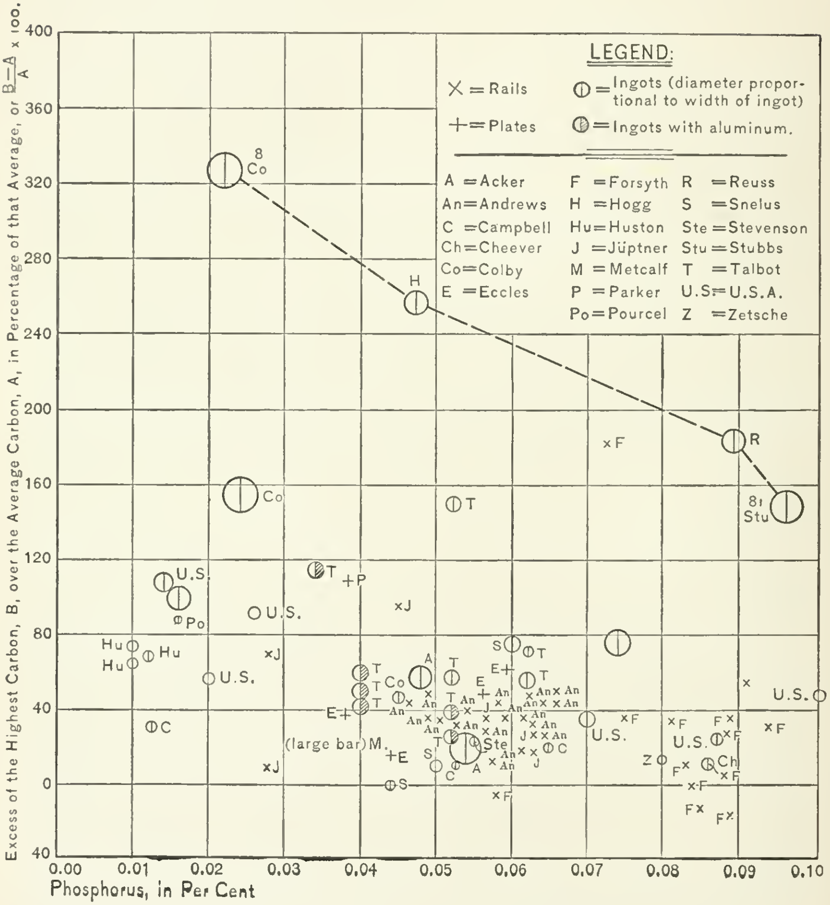

DIAGRAM II.—Influence of Phosphorus on the Segregation of Carbon.

If these inferences are right, then any harmful effect of low sulphur should be readily cured by a slight dose of aluminum, which quiets the metal wonderfully.

APPENDIX III.—THE EVIDENCE IN DETAIL CONCERNING PHOSPHORUS.

The General Trend of the dots in the cases shown in Diagram II is from west-northwest to east-southeast; in other words the segregation is inversely as the phosphorus. Let us first consider a few cases which tend to exaggarate this trend unfairly, and then consider some which seem to support it fairly.

Cases which Exaggerate the Trend.—Among these are the four large ingots connected by a dotted line, which form a row running nearly south east, a sort of northern boundary of the cases

INFLUENCE OF PHOSPHORUS ON SEGREGATION OF CARBON.

Segregation of carbon, or excess of richest point, B, over average, A; measured in percentage of that average, or $\frac{B-A}{A}\times 100$.

No.	Average Phosphorus.	Carbon.			Object.	Size, inches.	Authority.
		Average A.	Maximum B.	$\frac{B-A}{A}\times 100$ per cent.			
1	.01	.23	.38	65	Ingot	15x22	Huston.
2	.01	.23	.40	74	Ingot	15x22	Huston.
3	.01	.19	.32	68	Ingot	12x26	Huston.
4	.01	.81	1.06	31	Ingot	14x14	Campbell.
5	.01	.37	.77	108	Ingot	Large	U. S. A.
6	.02	.19	.38	100	Ingot	30x34	Huston.
7	.02	.23	.36	57	Ingot	16x18	....
8	.02	.26	1.11	327	Ingot	43x79	Colby.
9	.02	.28	.53	89	Ingot	10x10	Pourcel.
10	.02	.26	.65	155	Ingot	43x79	Colby.
11	.03	.39	.44	14	Rail	.....	Juptner.
12	.03	.29	.50	71	Rail	.....	Juptner
13	.03	.99	1.90	92	Ingot	16x18	U. S. A.
14	.03	.12	.25	114	Ingot	20x24	Talbot.
15	.04	.50	.80	60	Ingot	20x24	Talbot
16	.04	.50	.71	42	Ingot	20x24	Talbot.
17	.04	.50	.75	50	Ingot	20x24	Talbot.
18	.04	.12	.16	39	Plate	.....	Eccles.
19	.04	.10	.20	111	Plate	.....	Parker.
20	.04	.12	.14	17	Plate	.....	Eccles.
21	.04	.85	1.02	20	Large bar	.....	Metcalf.
22	.04	.42	.42	0	Ingot	13x13	Snelus.
23	.05	.19	.30	58	Ingot	30x48	Acker.
24	.05	.19	.21	11	Ingot	17x21	Snelus.
25	.05	.43	.60	38	Rail	.....	Andrews.
26	.05	.38	.60	58	Ingot	18x22	Talbot.
27	.05	.38	.53	40	Ingot	18x22	Talbot.
28	.05	.35	.68	94	Rail	.....	Juptner.
29	.05	.39	.57	46	Rail	.....	Andrews.
30	.05	.39	.54	39	Rail	.....	Andrews.

No.	Average Phosphorus.	Carbon.			Object.	Size, inches.	Authority.
		Average A.	Maximum B.	$\frac{B-A}{A}\times 100$ per cent.			
31	.05	.44	.67	52	Rail	.....	Andrews.
32	.05	.47	.62	32	Rail	.....	Andrews.
33	.05	.17	.19	11	Ingot	10x10	Campbell.
34	.05	.15	.18	20	Ingot	13 ton	Acker.
35	.05	.47	.66	40	Rail	.....	Andrews.
36	.05	.51	.75	47	Ingot	15x15	Colby.
37	.05	.24	.86	258	Ingot	30 dia.	Hogg.
38	.05	.38	.48	26	Ingot	18x22	Talbot.
39	.05	.38	.95	150	Ingot	18x22	Talbot.
40	.06	.57	.70	23	Ingot	12x12	Stevenson.
41	.06	.44	.60	36	Rail	.....	Andrews.
42	.06	.40	.48	20	Rail	.....	Andrews.
43	.06	.45	.66	47	Rail	...,.	Andrews.
44	.06	.42	.56	35	Rail	.....	Andrews.
45	.06	.41	.53	28	Rail	.....	Juptner.
46	.06	.40	.48	21	Rail	.....	Juptner.
47	.06	.30	.36	22	Ingot	10x10	Campbell.
48	.06	.45	.58	29	Rail	.....	Andrews.
49	.06	.11	.16	48	Plate	.....	Eccles.
50	.06	.36	.50	40	Rail	.....	Juptner.
51	.06	.43	.56	31	Rail	.....	Andrews.
52	.06	.49	.56	14	Rail	.....	Andrews.
53	.06	.47	.46	−2	Rail	.....	Forsyth.
54	.06	.15	.24	60	Plate	.....	Eccles.
55	.06	.43	.60	40	Rail	.....	Andrews.
56	.06	.49	.70	43	Rail	.....	Andrews.
57	.06	.44	.77	75	Ingot	19x19	Snelus.
58	.06	.43	.67	56	Ingot	20x24	Talbot.
59	.06	.43	.74	72	Ingot	13x16	Talbot.
60	.06	.43	.61	42	Rail	.....	Andrews.
61	.07	.62	.83	35	Ingot	19x19	U. S. A.
62	.07	.37	.54	48	Rail	.....	Andrews.
63	.07	.42	.60	43	Rail	.....	Andrews.
64	.07	.25	.70	180	Rail	.....	Forsyth.
65	.07	.68	1.20	77	Ingot	33 dia.	....
66	.08	.26	.36	39	Rail	.....	Forsyth.
67	.08	.52	.59	14	Ingot	.....	Zetsche.
68	.08	.33	.45	34	Rail	.....	Forsyth.
69	.08	.67	.74	10	Rail	.....	Forsyth.
70	.08	.39	.39	0.2	Rail	.....	Forsyth.
71	.09	.32	.28	−14	Rail	.....	Forsyth.
72	.09	.25	.27	11	Rail	.....	Forsyth.
73	.09	.09	.10	11	Ingot	13x13	Cheever.
74	.09	.69	.87	26	Rail	.....	Forsyth.
75	.09	.24	.32	35	Rail	.....	Forsyth.
76	.09	.24	.68	183	Ingot	15,400 lbs	Reuss.
77	.09	.37	.31	−17	Rail	.....	Forsyth.
78	.09	.89	1.11	25	Ingot	15x15	U. S. A.
79	09	.27	.41	52	Rail	.....	....
80	.09	.24	.31	29	Rail	.....	Forsyth.
81	.10	.37	.92	149	Ingot	39x39	Stubbs.
82	.10	.12	.18	47	Ingot	16x18	U. S. A.

shown in the diagram, beginning with the large Colby armor-plate ingot (No. 8-P. .02, segregation 327 per cent.) and ending with the large Stubbs ingot (No. 81-P. .10, segregation 149 per cent.). These four cases happen to stand out so prominently and so nearly in a straight line that they appeal strongly to the eye; but they deserve little weight, as I will now show. First the Reuss and Stubbs cases deserve little weight, because in each of them only a single analysis was made in the segregated part, so that the actual segregation may have been very much greater than that found. The Hogg ingot, on the other hand, was examined with great care and intelligence, by a systematic search through the segregated region, so that the great segregation in this case is probably very close to the true maximum. Again, while the fact that the single analysis of the Colby low phosphorus ingot (No. 8) found more segregation than the systematic search found in the higher phosphorus Hogg ingot (327 per cent. vs. 258 per cent.) agrees with the idea that segregation is inversely as the phosphorus, yet it may be due to the larger size of the Colby ingot (43 in. x 79 in. vs. 30 in. round), which in itself might tend to increase the segregation of the Colby ingot.

Forsyth Rail Cases.—The very low segregation in the Forsyth rail cases, shown by the marks XF in the lower right hand corner of the diagram, also seem to indicate that segregation is inversely as the phosphorus. But this reported low segregation may easily be due to the fact that while Mr. Forsyth knew that the segregate lay in the axis of the ingot, he probably did not know that it lay near the top of the axis, and that the lower part of the axis was really purer than the average of the ingot, as has since been clearly proved. The very low segregation which he found in the axis of certain rails, then, may be due to his having unwittingly taken those rails from the lower part of the ingot. Indeed, I have rejected a large number of cases reported by him which showed that the axis was really lower in carbon than the outside, as evidently due to this cause. These cases, if included, would have tended still farther to show that segregation is inversely as phosphorus.

The Andrews cases (X An) taken as a whole tend to show that segregation is inversely as the phosphorus. They deserve more weight than the Forsyth cases, because the drillings were taken at more points and more systematically.

Cases which are Fair Evidence.—The best of these are the six Talbot ingots with aluminum. These lie in a band running NW. and SE. Each of these cases represents a great many sets of drillings taken systematically from a good sized ingot. They are so fairly comparable among themselves and they indicate so consistently that segregation is inversely as phosphorus, that they form evidence of some weight. Again, although the use of aluminum lessens segregation, so that for given phosphorus (e. g. 0.05 per cent.) those without aluminum stand above those with aluminum; yet a comparison of the high-phosphorus ones without aluminum with the low phosphorus ones with aluminum tends to show that high phosphorus, counteracting aluminum, lessens segregation. Thus two of the Talbot .06 phosphorus ingots without aluminum have hardly more segregation than the .04 phosphorus one with aluminum, tending to show that the increase of phosphorus from .04 to .06 has about equaled the effect of aluminum in restraining segregation. Again, three of the higher phosphorus Talbot ingots without aluminum (P. .05 and .06) have decidedly less segregation than his .03 phosphorus ingot with aluminum, tending to show that here an increase of phosphorus of .02 or .03 per cent. is more effective than an addition of aluminum in restraining segregation.

The evidence is not conclusive for reasons already given; but the fact that in these cases the segregation is inversely as the phosphorus, and indeed the general distribution of the points in the diagram, certainly make against the idea that the low phosphorus lessens the segregation of carbon. Why it should do this I do not know.

GENERAL DISCUSSION ON STEEL RAILS.*

Mr. Webster.

Mr. W. R. Webster.—The different opinions expressed by the representatives of the Railway Companies and Rail Manufacturers, in the current discussion as to what would constitute a satisfactory rail, call to my mind the remarks of Sir Lowthian Bell during the discussion on "Recent Practice in Rails," at the Annual Convention of the American Society of Civil Engineers, in London, June, 1900. He said:

> "As I have been twenty-five years a manufacturer of rails, and twenty-five years a director in the Northeastern Railway, I represent both maker and user, and have at my disposal 35,000 analyses to go upon in making deductions. From these I can prove, and disprove, everything that can be said for or against any composition of a rail—a facility beloved by the expert."

Notwithstanding all this, if the important factors that have a direct bearing on the quality of the finished rail are considered, most of the conflicting opinions can be harmonized. The Committees at work on the problem are doing this. They are endeavoring to secure good uniform methods of manufacture by specifying chemical composition, amount of discard from top of ingot, finishing temperature in rolling, limit of camber in rails coming to the gag-press for cold straightening, and drop tests. They are nearer together now on these requirements than ever before, and it is to be hoped that a specification will soon be arrived at, by interchange of views, which will be acceptable to all.

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* This discussion covers the following:

Report of Committee A on Standard Specifications for Iron and Steel, embodying Proposed Standard Specifications for Steel Rails.—Wm. R. Webster, Chairman.

Mechanical Experiences with Limber and Stiff Rail Sections.—P. H. Dudley.

On Rail Steel as Manufactured by the Continuous Open Hearth Process.—Benjamin Talbot.

Mr. Webster. It must be admitted that the best rails are produced from steel low in phosphorus, rolled with light reductions and finished at proper low temperature. But the sections now in use make it almost impossible to continue the work of rolling on the head to a low enough temperature to produce the fine-grained structure desired. Therefore, a good starting point for this discussion would be the section.

In a recent discussion, it was claimed that the old Committee of the American Society of Civil Engineers kept in mind the importance of low finishing temperature, in designing their rails, and gave sections best suited for that purpose. As a matter of fact, the effect of the heat treatment of steel was not properly appreciated at the time the Committee made its report in 1892, and the sections do not permit of a low enough finishing temperature in rolling owing to the wide thin flanges. This, to a large extent, has caused the great trouble with 100-pound rails rolled to these sections. Other 100-pound sections gave trouble, and on March 25, 1901, I wrote, in part, to the American Society of Civil Engineers, asking for a new Rail Committee:

> "I would respectfully ask that a Committee be appointed to investigate and report on Standard Rail Sections. The reasons for asking for this Committee are that rails of 80 pounds and over are not giving good service. This is true of all heavy rails whether rolled to American Society Civil Engineers' sections or others. The cause of the trouble is now well known, it being due to the large mass of metal in the head carrying the heat so much longer than the thin metal in the flanges, thus preventing the work of rolling on the head at sufficiently low lemperature to break up the coarse grain and produce the tough, good-wearing rails desired."

The Board of Directors brought this up for discussion at the Annual Meeting in June, and the Committee was appointed in 1902. It is still struggling with the problem. In the arguments against the appointment of such a Committee it was claimed that sufficient evidence had not been produced to show that the heavier rail sections were not giving as good results as the lighter. Those present to-day must admit that the results of the past five years have given conclusive evidence that a change in section is advisable.

It has been the invariable experience in changing from a light to a heavy section, in any class of rolled steel, that difficulties have

Mr. Webster.

been met and modifications have been made in the methods of rolling, in order to get as good structure in the heavier sections as was formerly obtained in the lighter sections. In ordinary sections, other than rails, it was a comparatively easy matter to overcome the trouble and get a good structure; but the thin flange of the rail, and the higher carbons called for in the heavier sections, further complicate matters.

If a rail with the same width of head as the present American Society Civil Engineers' 100-pound rail is required, the head will have to be made thicker, and the radius under the head larger in order to prevent the sides of the head from shearing or breaking off as at present, and more metal put in the web and flange in order to carry the heat, thus allowing the head to be finished at the proper low temperature. This would mean a rail of about 120 pounds to 125 pounds per yard. I believe we are coming to heavier rails before we get rid of our present troubles.

In all justice, it must be admitted that a fair percentage of breakages is caused by the great increase of wheel loads since 1892, increase in speed of trains, use of large capacity steel cars, also that we do find poor track, poor rail joints, driving wheels not properly counterbalanced, flat wheels, etc. These conditions will no doubt be improved, but they must be considered in deciding on the rail for the future.

Open-hearth steel rails of the present weight and section, rolled under the present conditions of manufacture, cannot be relied on to overcome all troubles.

Most of the basic open-hearth steel manufactured in this country, is much lower in carbon than required for rail steel, and it is therefore much easier to control the uniformity of such steel. The common practice in Bessemer steel rail mills is to allow ten points leeway in carbon, and some of the basic open-hearth mills claim to work within these limits, but even as high as eighteen points leeway has been asked. It is easier to work within narrow limits of carbon in the acid open-hearth steel process than in the basic.

What is wanted is a steel as nearly uniform in carbon and other chemical elements as possible, without inflicting too great hardship on the manufacturer. We desire full expression of opinion from the basic open-hearth steel manufacturers as to just

Mr. Webster. what chemical requirements and limits they would agree to work to in rail steel.

It would be a very simple matter to roll a thousand tons of extra heavy rails of basic open-hearth steel, and one thousand tons of same section of Bessemer steel, with enough metal in the web and flange to carry the heat and finish them in rolling at the lowest possible temperature without injuring the metal in the flange. In other words, approach as nearly as possible the rolling conditions of the old bull-headed rail, which has been rolled with only 4½ inches shrinkage allowance in a 30-foot rail. Let the chemical composition, per cent. of discard, and conditions of manufacture be in accordance with the best modern practice. The expense of preparing rolls and rolling such rails would be trifling in comparison with the information obtained, and the rails would be better than any heavy rails ever rolled.

Mr. Dudley. MR. P. H. DUDLEY.—Mr. Webster handed me a copy of his discussion on rails for present and future requirements of the railroads, also Mr. Talbot's on rail steel as manufactured by the continuous open hearth process and his suggested sections.

I wish to place upon record, as a matter of fact, in introducing the use of five- and six-inch rails in this country, knowing that the metal in sections of greater mechanical properties would require also increased physical properties to sustain the traffic, I insisted upon this provision in their manufacture. This was opposed generally, except by the Time-Honored Iron Master, Mr. John Fritz. There are over a million tons in service of the five-inch and higher sections in 75-, 80-, 95- and 100-pound rails which were made in accordance with my specifications, starting in 1884 but particularly in 1891. The tonnage on some of the 100-pound rails has exceeded 350,000,000 tons; others 300,000,000 tons, and the rails are still in service; 150,000,000 to 200,000,000 tons are about the limit reached on the 80-pound rails except in a few places. A greater tonnage has been carried by the heavy rails than by the light rails they replaced. I, therefore, from experience, with my own sections, do not concur with Mr. Webster, "that the wear has been unsatisfactory upon all 100-pound rails." I made the fillets under the heads of my sections ½ minutes radii which makes a stronger support for the underside of the head than those of less radii.

One of the important features of any section is to secure sound

Mr. Dudley.

steel in the ingot for the desired physical properties in the metal and this impart must be by the chemical composition with sufficient time for the reactions of the re-carburizer and escape of the slag formed before the steel is teemed in the ingots.

Subsequent cold rolling in any form of section will not make sound steel having minute slag inclusions either for wear or for the section as a girder. The latter controls the physical properties of the metal which may be used under the heavy wheel loads large expenditure of the tractive effort and high speed trains. The metal must be capable of withstanding in zero or lower temperatures when the steel in the section is under thermal stress due to the falling temperatures before the ends of the rails have rendered in the splice bars.

The cold waves of the past winter in most localities were continuous for several days and the weather cloudy, the sunshine not relieving the severe tension set up in the rails during the night. The friction of a 5-inch splice bar is from 4,000 to 4,300 pounds per lineal inch of its length and 80-pound rails might carry a thermal stress of 70,000 to 80,000 pounds and the 100-pound rails 90,000 to 100,000 pounds before the splice bars would render. These or smaller stresses due to the falling temperatures in addition to those of passing locomotives caused many rails to check in metal formally disturbed in the straightening presses and finally fracture from repeated strains in zero or lower temperatures.

A railroad in territory where low temperatures yearly occur must have metal in the rails of a quality to withstand such conditions, not experienced by railroads in warmer climates. The different conditions under which railroads are operated account in part for the difference in opinion in reference to quality of metal for rails. The increase in the number of square inches in the section will subject the rails to larger thermal stresses in low temperatures.

The problems either for the consumer or producer are serious for they involve the safety of human life for which the consumer as the first party is directly responsible.

The axle loads have doubled in the past 15 years and the requirements for sound and safe rails exceed what some producers consider ample. The heavy sections, when made in ingots of 6,000 and 7,000 pounds rolled in four or five lengths, should be bloomed

Mr. Dudley. at first with light draft passes until the skin is toughened to prevent the numerous checks in the bloom which are closed but not rolled out in the finished section, and often become the incipient point of fracture. The rails in the track, besides carrying the vertical loads, receive lateral shocks which often start the fracture in the base of the rail.

Mr. Jones. MR. M. T. JONES.—I am convinced beyond a question of doubt, that the majority of broken rails can be directly traced to fractures caused by the gag, and in looking over the several reports from various sources during the recent agitation I fail to find in any one of them where the responsibility has been placed in this direction. I feel perfectly safe in saying that if this matter is properly investigated my assertion will be found to be true, and in support of same I will offer the following comparison:

Take the rail that is submitted for drop tests. This test piece is cut from the front end of the first rail rolled and comes from the top of the ingot, and after being allowed to cool off naturally we find, in almost every instance, it will resist the enormous shock it receives under the prescribed test. Then, again, take a test piece from the same rail after it has received several blows from the gag in straightening and subject this piece to the same test, placing it in position so that the drop will fall directly upon a point at which it has been gagged, and I will venture to say it will not show the same results, and I firmly believe this is the all-important point to be taken up, with a view to finding a remedy.

It was my intention to make an appeal to the Convention on this subject and see if it would not be practicable to straighten a rail by running it into fixed casings covering the flange and web its entire length, allowing enough space around the parts encased to take up the contraction and prevent it from warping out of line and surface, and if the railroad companies decide to remodel their sections, allowing more metal in the base or flange of the rail, I believe the contraction would be so moderate that this could be accomplished. The rails could be forced into these casings through a set of dummy rolls placed in position at the point of entry to the casing, and while to inaugurate this system would appear to be a costly one to the manufacturers, they should not lose sight of the fact that in the long run it would be a great saving to them; besides getting the desired results it would do away with straighteners, gaggers, straightening machines and cost of maintaining same, and the space now taken up in the finishing department by these machines could be utilized for cooling beds, and would, therefore, avoid the necessity of making very little change in this respect. **Mr. Jones.**

I would like, if you deem it advisable, to have this question brought up during discussion on this subject so as to allow those interested to express their various opinions as to the practicability of my suggestion, and if it be found to be practicable it would be an easy matter to figure out the form of casing required and other mechanical devices to put it into practice.

I had also intended to say a few words regarding the question of inspection, and the manner in which it is conducted to-day by railroad representatives, and in forming specifications I would suggest that a clause be inserted compelling the mills to do their loading in reasonable hours, say between the hours of 6 A. M. and 6 P. M. As it now stands some of the mills commence loading shortly after daylight and continue to sundown, which necessitates doubling the force of inspectors if all the rails are to be inspected, and I am of the opinion that an inspection is practically worthless if only a part of the rails are inspected, as that is just when defective rails are liable to get away. This is a question many of the railroads have failed to give proper attention to, as in many instances they appoint representatives without knowing their qualifications to fill the positions, and owing to the inexperience of these inspectors they are more or less afraid to offer protest when rails do not conform to specifications, and they pay very little attention to the quality of the rails as they seldom make any effort to walk over them. It would be well for the railroads to look into this as it would materially help to better the results.

Mr. Hunt. Mr. R. W. Hunt.—I think, in the first place, that the statement made by Mr. Webster that the sections under existing conditions form the basis upon which intelligent discussion rests and from which intelligent results are to come, is absolutely true; because I do not care how good the steel may be, how careful the manufacturer may be in its manipulation, if the section is wrong there will be unsatisfactory results. I think Mr. Webster is wrong in his assumption that at the time of the adoption of the American Society sections by the Society's Committee, the question of temperature was ignored, because, as a member of that Committee, I

Mr. Hunt. know that was one of the points which received most careful consideration, not only by discussion between the members of the Committee, but also in consultation with rail manufacturers. But a peculiarity of the situation comes from the fact that at that time what we now consider sections of necessary weight were then not in general use. We were instructed to advise sections from 100 pounds per yard down, decreasing by 5 pounds, but 80-pound sections were then regarded as the heaviest likely to be extensively used. I believe only one railroad at that time had heavier sections, and that was the Philadelphia and Reading which had a few 90-pound rails in use. The New York Central had put in 80's and perhaps they had a few heavier rails, but their standard was the 80. The Delaware and Hudson had adopted the 80, also the Michigan Central, and as well as I can remember that was about the status. So that the question was to devise a section which the Committee considered a good one and which the manufacturer said could be easily rolled. Unfortunately, the sections beyond 80 pounds were matters of compromise and they progressed, as you know, arithmetically, with the result that, in my judgment, we have less satisfactory results as the weight has increased. We are now at a point when I think we ought first to make a radical departure in the design of the heavier sections; but it will not do a bit of good, no matter what may be the design, unless the manufacturers will make it carefully and put good steel into it; and in my judgment, based on many years' experience, they cannot do that unless they take more time in the operations incident to the making than is now generally the case. Mr. P. H. Dudley referred to the fact that the results which were obtained from rails made when time was taken between the pouring of the steel from the converter into the ladle, and the teeming of that steel into the ingot, were much more satisfactory than they have been since such practice was abandoned.

All of us who have made special steels by the Bessemer process, understand the importance of giving the metal time for thorough chemical reactions, and for the escape of the gases. We learned, and practised this when making gun-barrel, axle, and drill steels. We found that we had to take time. I remember one thing that we practised at Troy in making these special steels which was of great value to us; it was, using the staves from the barrels in which our ferro-manganese had been imported. They

Mr. Hunt.

were barrels in which kerosene oil had been shipped abroad, and the foreigners used them to ship the ferro-manganese back. The wood was well saturated with kerosene and we found that by sawing those staves in two and throwing them into the molten steel while in the pouring ladle, we obtained sound ingots from which we rolled steel that the Winchester Company, Smith and Wesson, the United States Government, and others, used with satisfaction, and found free from slag or blow-hole defects. Rail making is not so far away from this, and it is just about as important that we should take as much pains in making a rail suitable for the duty it has to perform, as we did in making a gun barrel with which somebody was to be killed.

I say, with all due respect to my friends, the rail makers, they will have to build more mills to produce the same tonnage. They know as well as I do that time is an element which they are trying to ignore. It reminds me of the experience that happened to a young mechanic we had in Johnstown years ago. He was a molder, and was the best one we had at the Cambria Works. The work there was on machine castings entirely. Well, he got too large for his field, and in those days Troy was the center of the stove industry, so he concluded he would go to a place where expert and rapid workmen were appreciated. He secured a job in Troy, but in a couple of weeks was back at the Johnstown foundry. Somebody asked him, "What is the matter?" Couldn't you keep up with those Troy fellows?" He replied, "Keep up? Why if you stopped to spit you were just that much behind at night." And so it is in the rail mills: any fellow who turns his head there is lost. Now that won't do. In the old days we found it necessary to take time, and I believe nothing has happened to make it different now. We then took time in blowing the steel; we took time in pouring it; and then in rolling it. The rolls were of smaller diameter, the engines were of less power, therefore the reductions had to be lighter; and when defects were found after the steel was reduced into the shape of a bloom, they were chipped out. That has all been abandoned, simply because it took time, held down the product, and of course increased the cost. The rails which are now made are of larger sections, and, of necessity, receive less work than did the smaller ones. Then we have put in larger diameter rolls, increased the power of the engines driving them, and, worst of

Mr. Hunt. all, reduced the number of passes used in rolling the rails. So that as we have gone away from the work, and gone away from the possibility of work, we have decreased that which the steel should receive, and given that which it does get in the worst possible way. It will be observed in a modern mill that as the ingots are drawn through the first passes of the blooming rolls in a large majority of cases, there will develop large cracks running across the entire face of the ingots. Now there is no subsequent operation of the rolling process that will weld those cracks up. The cracks are elongated, and may apparently disappear, but the defects are still there, and I believe that many a subsequent mysterious failure of rails made from such ingots, if we could trace it back, would be accounted for by the cracks developed in the blooming rolls.

But first let us have a section without so much of the metal in the head, and with more in the flange, so that the structural strains that have been referred to will not be developed to so great an extent; and what is of quite equal importance, the whole rolling process can be conducted at a lower temperature.

There are some points in these proposed specifications which I must beg leave to criticize adversely. In the first place, Clause 3 states the drop test shall be one piece taken from each fifth blow of steel. I have always been radically opposed to that, because if it is necessary or important to have a drop test at all, you should have it from every blow; and the only argument that is offered against it is that it will add to cost and interfere with the product of the works, because it will take time. Now that is not exactly a correct statement, because if it is necessary there is nothing in the world to prevent works having more than one drop-testing apparatus. Compared with the total cost of the plants, such an addition would be very insignificant, and with it they would not be delayed while waiting for tests. But what is the use of having it at all if you can only have it every fifth heat? You might about as well have it once or twice a day, one in the morning, and then again in the afternoon, and if those proved satisfactory, we would assume everything between must have been right. One test out of every fifteen tons is infrequent enough, without multiplying that by five. Therefore I am radically and positively opposed to that clause. I think there should be a drop test from each blow of steel.

Then as to the finishing temperatures, Clause 4, while that perhaps is worded as well as we can get it just now, I believe we **Mr. Hunt.** will soon be more radical, and instead of leaving the speed of the train and the number of passes indefinite, as it is here, limiting it simply by a finishing temperature, it will be brought about, through conferences, and otherwise, that the number of passes and heat treatment will be specified; because I am positive it is a mistake to assume that anything of the structure of steel can have the same thing accomplished in the changing of that structure regardless of the application of heat and force. In other words, we will take an ingot that is, say 22 inches by 20 inches square, and we know it has a very coarse crystalline structure. Now is it illogical to assume that if we take a large number of passes and slow reductions to bring that metal down to an area of 8 inches square, we will not get different results than if we brought it down through the application of greater force in a much smaller number of reductions? I am very positive that is true. The fact that the present reductions tear the metal is evidence that it should be treated differently. Small reductions will not so rupture it. At present I haven't anything to offer as to the number of passes, but I believe that the conferences which are to take place between the purchasers and makers will lead to some important changes in this part of the process.

Now, Mr. President, if it is going to cost more money to do this let us treat the question fairly. If $28.00 a ton is not enough, let the makers show their hands, and state what will be enough, and then it will be up to our friends, the railway companies, to say whether they will pay it. I am sure they want the makers to make a handsome profit, as they deserve to do, but they also want them to give them something in return. We don't want cotton velvet when silk velvet is proper and paid for.

Section 6. I think we should change that somewhat, for the analysis of the average of a turn's work is not close enough; because it is not the average that you get in the rails; it may be one heat of steel that had phosphorus or other elements beyond the limit. With the quick analytical process that we now have, this ought to be treated in some closer way. In other words, I think it is just as necessary to know the phosphorus in every heat as it is to know the carbon.

Section 7. That I have already referred to, because I do not

Mr. Hunt. think the so-called American Society sections are the proper ones.

I am glad to see that the Committee have modified their action and adopted that five inches restraint in regard to the line of the rail when it comes from the hot-bed. Undoubtedly we all recognize the great damage which is done to the rails in the cold-straightening press by the gagging, and I know that all of us who are familiar with the operation have frequently seen rails hit fearful blows; for instance, a rail 33 feet long could be hit near one end a blow sufficiently hard to make the other end jump through an arc of 18 inches. Now is there any wonder that something deleterious to that steel took place at the time that blow was struck, and is it any wonder—that blow was struck where the drill holes were to come, the bolt holes—is it any mystery if that rail breaks without any seeming cause? That fracture was started at the mill. And just now the epidemic break is the crescent shape one coming out of the flange. In almost all—in seventy-five per cent. of the cases—it will be found that there is a lap in the steel at the base of that break. That comes from the design of the rolling passes aggravated by the cold gagging. You can always find on any rail after it has lain a short time, that the metal has been disturbed by the gagging, and the mark is in the shape of those breaks. In my judgment a very large number of failures come from undue work in the cold-straightening press. I think the limitation of five inches is a very moderate one. The American Railway Engineering and Maintenance of Way Association have made it three inches. It will insure more careful work at the mills and, perhaps, not quite as fast work. They must have more hot-bed room, they must take more pains in cambering the rails, in fact more care in all the details of hot-straightening than they have in the past.

The specification as it applies to No. 2 rails I think is wrong. The Pennsylvania Railroad designation of No. 2 rails has been accepted as a trade one for years, and many specifications have been drawn so. I have always recognized it in any which I have prepared. It limits the depth of the permitted defects in the flange and in the head, and the number of them. These specifications have no such details, and would permit rails that have failed under the drop tests to be taken as No. 2 rails. Such rails are not of necessity defective. They may be perfect in contour without checks or flaws. If taken, they go out on the road and their identity as No. 2 rails may become lost. The track master thinks the rail a good one, and, unknowingly perhaps, puts it where it or no other No. 2 rail should go. Therefore I think the characterization of the No. 2 rail should be made more definite, and a permanent marking, by prick punching or otherwise, specified. **Mr. Hunt.**

I most seriously object to putting the acceptable quantity of second quality rails at 10 per cent., since 5 per cent. is, and has for a number of years been, the quantity which the railways have agreed to accept. It will be recalled that in the earlier history of the steel-making industry in this country, the Eastern roads did not accept any second quality, but the Western ones practically always accepted 5 per cent. and it will also be recalled that the former contracts read that 5 per cent. of seconds would be accepted in addition to the quantity specified in the contract, if they were made while the contract was being filled. This limitation was gradually eliminated, until of late years it has generally been specified that 5 per cent. of seconds would be accepted. I feel very positive that the railways will object to having that quantity doubled, and I do not see why it should be. It is supposed that second quality rails are used on sidings, and in yards, and they certainly should never be put into a main-line track. If this practice is strictly adhered to, of course, the quantity which can be legitimately used is limited.

While I will admit that in the production of the heavy sectioned rails, there will be a greater percentage of second quality ones produced than in the rolling of lighter sections; at the same time I know that there are mills now rolling heavy sections whose percentage of second quality rails does not exceed the 5 per cent. limit; and certainly we do not want to put a premium on the production of undesirable rails.

Mr. H. V. Wille.—The following conditions govern the service of a rail: **Mr. Wille.**

1. Chemical and physical properties of the rail itself.
2. The design of the rail.
3. The ballast and condition of roadbed.
4. The weights the rails are required to sustain.

Chemical and Physical Properties.—This Society is more directly concerned with these features than with any other, and they have been the source of the most discussion. It is, however, one that can be most readily determined upon and fixed.

Mr. Wille. If rails are made from material of an approved composition it then remains to give the ingots a sufficient reduction in rollings to finish them at a sufficiently low temperature and to discard enough from the ingot to insure a good rail. These features can be and should be all definitely fixed in a specification and there should be no option whatever allowed. If it is necessary to discard 20 per cent. it should be positively fixed in the specifications. It is altogether wrong to specify 5 per cent. and to give the purchaser the privilege of specifying a greater discard provided an additional price is paid. It is not necessary to specify a proviso of this kind, for every purchaser has a natural right to it and may exercise it regardless of specifications, and such a qualifying clause only stands as an apology for the specified discard.

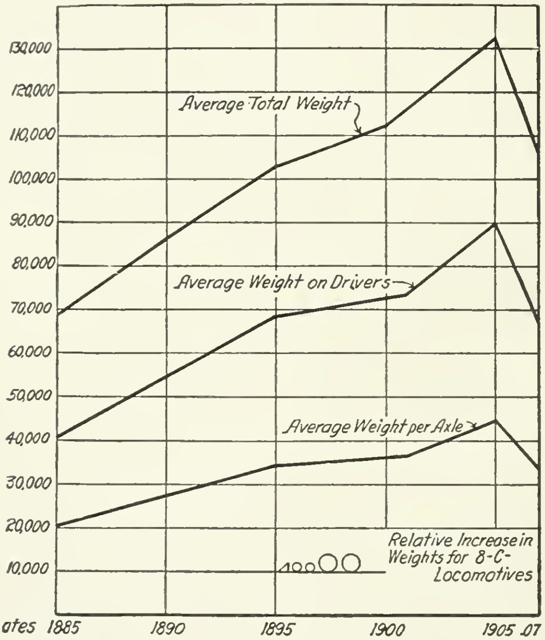

FIG. 1.*—Increase in Weight of 8-Wheel Locomotives.

The limitations on impurities in rails have been rather definitely fixed for a number of years. There has been a decided tendency, however, to use a steel of a higher carbon than formerly, especially in the lighter sections. There is no reason, however, for the proposition of making the heavier rails of lower carbon than the lighter sections. If the higher elastic limit of the .60 carbon steel is preferable for the lighter sections, it is equally advantageous for the heavier sections, and affords an additional margin **Mr. Wille**

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* Acknowledgment is made to the *Railway and Engineering Review* for the cuts used in this paper.

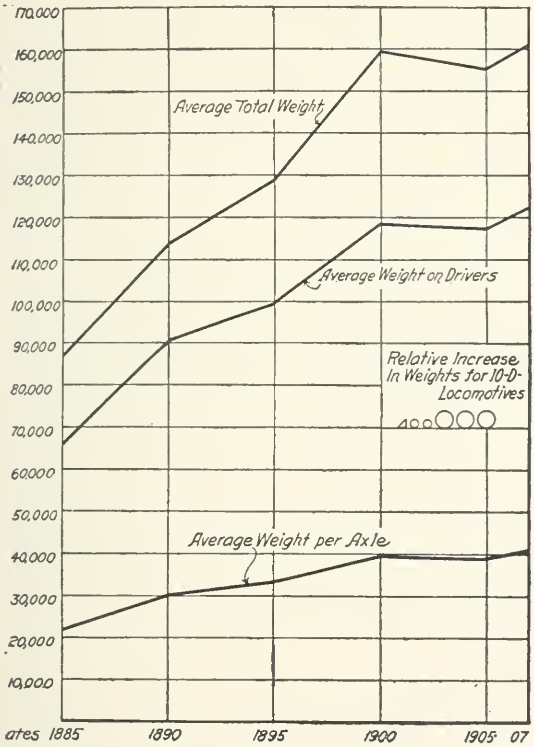

FIG. 2.—Increase in Weight of 10-Wheel Locomotives.

of safety. If the higher carbon is used on account of wear there should be no distinction in carbon.

Inasmuch as all weights of rails are rolled from the same size ingot there is much less work of reduction on the heavy rails than upon the lighter sections. This will not only affect the wear but also the brittleness. The present specifications do not go far enough. They should not only specify the chemistry and physical

Mr. Wille. tests, but they should also definitely specify the discard and the amount of reduction from the ingot. If this is done the drop test is merely a check and assumes minor importance.

There is but little accurate data available upon which to base the design of a rail. It is well known that the weight of rolling stock has increased enormously during the past decade but I have never seen exact figures on this subject. This is not only true of locomotives but of cars as well. The locomotive weights have been considered of first importance in deciding upon the type of rail that is to be employed on account of being heavier than cars. The weights of cars, however, should be given more prominence than they are given, as the load is more intensely concentrated than those in locomotives, because of the smaller diameter

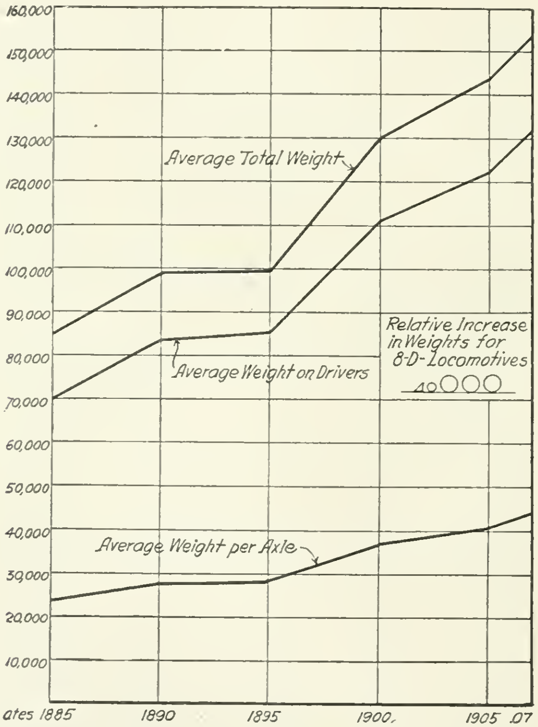

FIG. 3.—Increase in Weight of Mogul Locomotives.

of the wheels. When cars pass certain points on the rail the loads are repeatedly applied and it is the repeated application of loads that induces fatigue. For instance, in a one-hundred-car train with four-wheel trucks, the carloads are applied four hundred times in rapid succession. **Mr. Wille.**

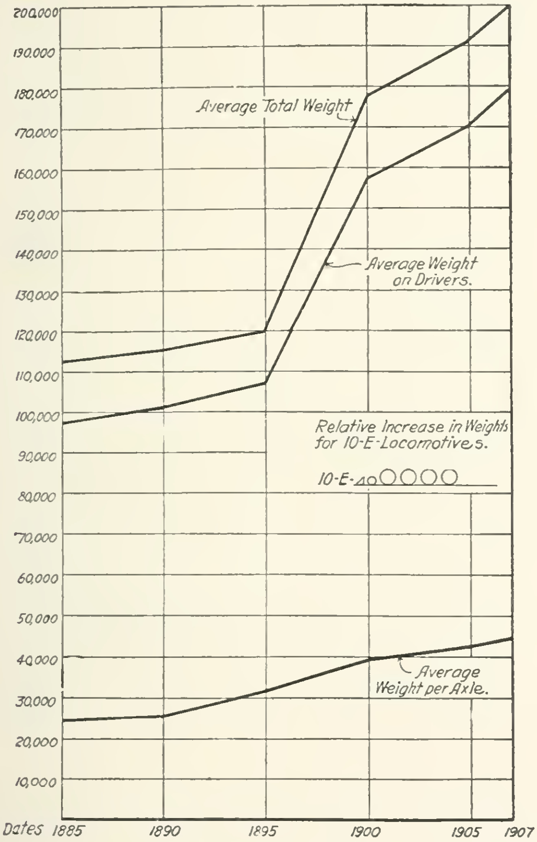

FIG. 4.—Increase in Weight of Consolidated Locomotives.

There does not appear to have been any systematized effort to ascertain whether the strength of the rail has increased in the same proportion to the increase in rolling stock loads, and as a first step in this direction, I have tabulated

Mr. Wille.

1. The total weight of engine,
2. The total weight on drivers,
3. The average axle load,
4. The per cent. increase of loads,

for each type of road engine which was built by the Baldwin Locomotive Works for the years of 1885 to 1890, 1895 to 1900, 1905 and for the first half of 1907. I have shown these results in tabular form and have also plotted them in the diagrams presented herewith. All engines for export, as well as those built for switching, logging, mining and industrial service have been eliminated.

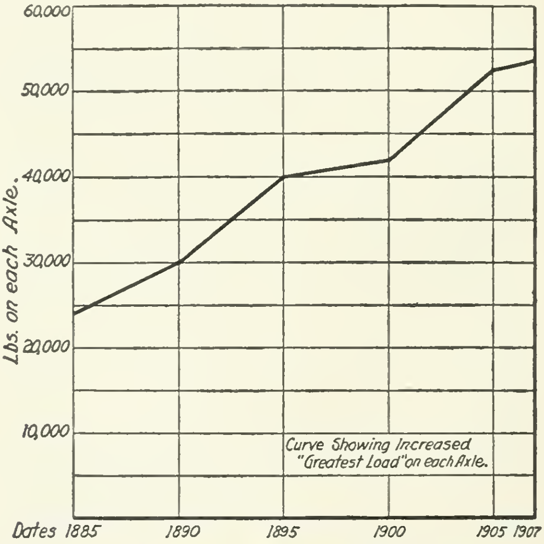

FIG. 5.—Increase in Maximum Axle Loads.

The diagrams show that the typical American passenger and freight engines have increased 90 per cent. since 1885, both in axle loads and in total weight on drivers. During the first ten years the Consolidation engine, which is the favorite freight engine of the present day, increased but 7 per cent.; the Mogul engine, which was largely used for a freight engine in the decade of 1880 to 1890, increased 17 per cent., while the ten-wheel engines increased 49 per cent. The latter engines practically attained their greatest weight during the period from 1895 to 1900. During

Mr. Wille. this period the Mogul and Consolidation engines increased 60 per cent. in weight, and from 1900 all these classes converge to a common point of an increase of about 85 per cent.

These diagrams indicate that the next step was the employment of a greater number of driving wheels. This, in fact, has been the tendency of a number of roads during the past few years, the Atchison, Topeka and Santa Fé Railway, the Northern Pacific and Great Northern being the pioneers in this field.

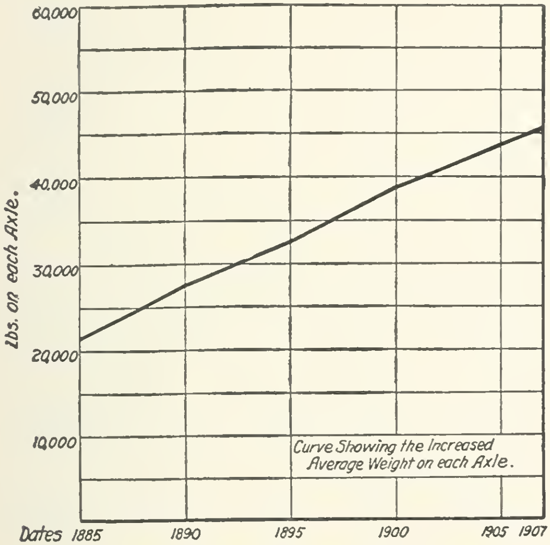

FIG. 6.—Increase in Average Axle Loads.

In 1885, the American type 4–4 engine was the standard passenger engine, having about 40,000 pounds on drivers, and the Mogul, or ten-wheeler with 68,000 pounds on drivers, the standard freight engine. In 1895 these types were still largely employed, the former having reached 68,700 pounds and the latter 99,400 pounds on drivers. In this decade the Atlantic type engine was brought out with 80,000 pounds on the drivers.

In 1900, the American type engine was almost entirely superseded by the Atlantic, Pacific and ten-wheel types of engines, having 85,000 pounds on drivers for the former, and 118,000 pounds for the latter. During this decade the Consolidation, with 157,000

Mr. Wille. pounds on drivers, almost superseded the lighter types of engines previously used.

The decade of 1905 witnesses the advent of the Santa Fé type engines and of the Mallet Compounds with 233,000 and 316,000 pounds respectively on drivers, while the Atlantic and Pacific types have almost monopolized the passenger traffic.

It will be thus seen that while the total weights and axle loads are both increasing there is a tendency to distribute the load among a greater number of wheels as has already been done by the three roads mentioned.

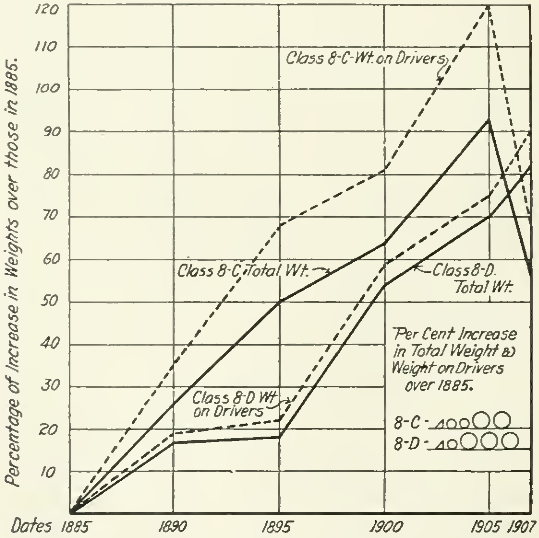

FIG. 7.—Percentages of Increase in Weight of 8-Wheel and Mogul Locomotives.

Fig. 1 shows the increases in total weight, weight on drivers and average weight per axle for eight-wheel locomotives. It will be seen that the maximum figures were reached in 1905, since which time there has been a decided falling off, owing to the practical abandonment of this type of locomotive in favor of Atlantic, Pacific and Prairie locomotives for passenger service on lines of heavy traffic. The highest driving axle loads are 45,000 pounds.

Fig. 2 shows the same data for ten-wheel locomotives (4–6–0).

Mr. Wille.

The average total weight has increased from 87,000 pounds to 161,000 pounds, or 85 per cent., and the average weight on drivers has increased from 65,000 pounds to 122,000 pounds, or 88 per cent. The average weight on each driving axle was 21,900 pounds in 1885 and 40,600 pounds in 1907.

Fig. 3 is for Mogul engines. The average total weight increased from 85,000 pounds to 154,000 pounds, or 83 per cent., and the weight on drivers from 70,000 pounds to 133,000 pounds, or 90 per cent. The driving axle weights rose from 23,500 pounds in 1885 to 44,000 pounds in 1907.

Fig. 4 is for Consolidation (2–8–0) locomotives. The average total weight increased from 112,000 pounds to 200,000 pounds, or 79 per cent., and the average weight on drivers increased from 97,000 pounds to 179,000 pounds, or 85 per cent. The driving axle weights rose from 23,250 pounds in 1885 to 44,750 pounds in 1907.

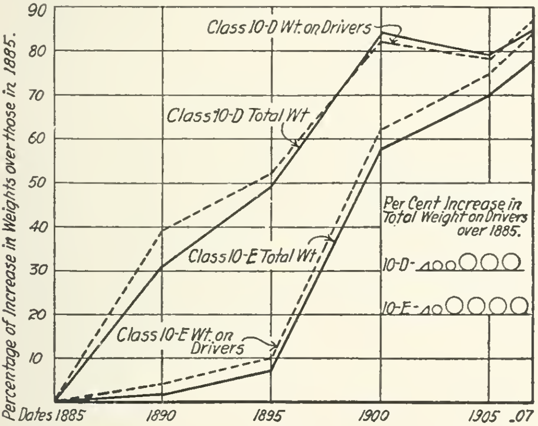

FIG. 8.—Percentages of Increase in Weights of 10-Wheel and Consolidated Locomotives.

Fig. 5 shows the increased maximum axle loads, the highest in 1885 being 24,000 pounds and the highest in 1907 being 53,500 pounds. The increase is 123 per cent.

Fig. 6 shows average axle weights for all types of locomotives, the increase in 22 years being from 21,500 pounds to 45,500 pounds, or 112 per cent.

Mr. Wille. Figs. 7 and 8 show the data tabulated as percentages.

These diagrams are very interesting and I will briefly recapitulate their significance.

1. The average total weight on drivers has increased from about 69,000 pounds in 1885 to over 180,000 pounds in 1907, and has reached a maximum of 316,000 pounds.

Class.	Average Total Weight.	Average Weight on Drivers.	Aver'ge Weight on Axle.	Number of Engines.	Class.	Average Total Weight.	Average Weight on Drivers.	Aver'ge Weight on Axle.	Number of Engines.
		1885.					1900.		
6½ C	58,000	50,000	25,000	1	6½ C	58,500	47,000	23,500	1
8 C	68,600	40,800	20,400	76	8 C	112,500	73,870	36,930	8
8¼ C	57,228	37,078	18,539	5	10¼ C	151,000	83,800	41,900	32
8½ C	50,000	35,000	17,500	2	8 D	130,000	111,000	37,000	21
8 D	84,300	69,900	23,300	33	10 D	159,400	118,700	39,560	148
10 D	86,700	65,200	21,730	27	10¼ D	156,500	117,400	39,130	32
10 EE	112,250	97,125	24,281	8	10 E	177,400	157,500	39,370	307
10½ E	60,000	52,000	13,000	1	12 F	214,000	190,000	38,000	1
		1890.					1905.		
6 C	58,000	49,000	24,500	1	8 C	132,400	89,800	44,900	25
6½ C	66,500	61,500	30,750	2	8¼ C	113,000	80,000	40,000	1
8 C	86,600	54,900	27,450	35	8½ C	60,000	42,000	21,000	1
8¼ C	54,000	37,500	18,750	4	10¼ C	199,000	104,000	52,000	104
1c¼ C	80,000	44,000	22,000	1	8 D	143,700	122,400	40,800	77
8 D	98,900	83,300	27,700	82	10 D	155,400	117,800	39,260	176
8½ D	92,000	88,000	29,300	1	10¼ D	198,500	141,400	47,130	112
10 D	114,000	90,400	30,100	130	12¼ D	225,000	147,000	49,000	113
10 E	115,100	101,200	25,300	101	16¼ DD	345,000	316,000	52,660	5
12 E	121,620	94,400	23,600	10	10 E	191,000	170,500	42,600	720
					12 E	197,000	165,800	41,700	51
					12¼ E	231,000	181,000	45,200	13
					14¼ F	285,700	233,000	46,600	52
		1895.					1907.		
6 C	77,000	64,000	32,000	1	8 C	106,000	68,000	34,000	1
8 C	103,000	68,700	34,350	44	10¼ C	201,000	107,000	53,500	35
8¼ C	89,500	60,000	30,000	4	8 D	154,000	132,000	44,000	26
10¼ C	132,000	80,000	40,000	12	10 D	161,000	122,000	40,600	157
8 D	99,700	85,400	28,460	14	10¼ D	213,000	155,000	51,600	116
10 D	129,000	99,400	33,130	73	12¼ D	217,000	143,000	47,600	51
10¼ D	92,500	71,500	23,830	2	10 E	200,000	178,800	44,700	412
10 E	120,000	107,000	26,750	23	12¼ E	224,000	180,000	45,000	4

2. The average axle load has increased from 22,000 pounds in 1885 to 48,000 pounds in 1907.

3. The percentage of increase for the various classes of engines all converge toward a common point showing that the increase is being cared for by distributing it among a greater number of drivers.

It would throw a great deal of light on the rail matter if data similar to that which I have collected for locomotives, be tabulated for freight and passenger cars and for weight and strength of the rail section, and such figures would give our engineers reliable statistics upon which to base their deductions. **Mr. Wille.**

Mr. J. E. Howard.—It is desired, during the coming fiscal year, at Watertown Arsenal, to devote attention to questions pertaining to iron and steel, beginning with the ingot and following the processes of working through the successive stages of manufacture, and it would seem that the resources of the laboratory might be utilized in the direction of questions pertaining to steel rails. The examination should preferably begin with the metal in the ingot, since it seems to be established that in the case of certain defects, that is those of structural continuity or the lack of the same, that subsequent treatment may in a degree obscure these defects, but not obliterate them. In the examination of a few ingots the lack of structural continuity has been a pronounced defect, and such defects are shown in photographs which have been prepared. **Mr. Howard.**

In taking up the matter of ingots and proceeding to the finished product, it would afford the Arsenal authorities great pleasure to assist in any manner toward solving the current questions pertaining to steel rails, and, furthermore, it would promote the Arsenal investigations to have the assistance and co-operation of railmakers and users in the procurement of the necessary material.

Mr. C. S. Churchill.—According to my way of thinking and looking into the matter of rail failures on our road, we do not entirely agree with Mr. Webster in his conclusions. The part of his conclusions relative to changing the section of the rail so as to make the head and base more nearly equal we do agree with. But the idea that the head must be enlarged in order to counteract the shearing strain produced by the rolling load we do not agree with; and I do not believe it can be possibly proven that the steel that we are getting, or rather that we are specifying and expect to get from the mills, if we do receive it, does not have the proper strength to carry those loads. It seems to me that the proof of this position is very clear, if we bear in mind that railroads do not step up to the higher section of rail at one time. It takes a long period of years to step from a light rail to a heavier rail. For example, the Norfolk **Mr. Churchill.**

Mr. Churchill. and Western adopted the 85-pound rail in 1894 as their standard, but to-day we do not find 85-pound rails over the entire system. In the year 1898 some 75-pound rail was bought, irrespective of our standard, for a section of road where light traffic at that time was being handled, but generally 85-pound rail has been purchased since 1894. Now if the conclusion that light section rail was too light for the service is correct, then we would expect that the lighter sections that still remain in track would be breaking more frequently than the heavier sections. Such is not the case. Sixty-seven-pound rail still in track does not break as often as some of the heavier sections recently bought; and this disproves that theory.

Further, upon examining sections of broken rail there seem to be incipient flaws in the rail that do not develop until, in some cases, long after the rail has been in use. Dr. P. H. Dudley's explanation is to the point, and agrees exactly with our findings. A very good example with us was in the case of some 75-pound rail that we put in track in a straight section of railroad in Ohio in 1898. That rail has given us very good service. But about two years ago we increased the weight of our engines on that particular division by only ten per cent. There developed suddenly a large number of breaks in that rail. Now those breaks were not where the heavy strains came, but they were generally near the center of the web. A few of the breaks were in the flange, these being crescent-shaped. They did not cause us much trouble, because our section men discovered them when they first appeared as a very fine hair-like crack which would gradually become larger and rust.

Now to my mind that proves conclusively that there were incipient flaws in those rails that were not discovered until the load came on them that was just enough to develop the flaws. And that is again the explanation why Dr. Dudley's section that he has passed around here also developed and broke in six months. We had a similar case recently, in which a passenger train on an 85-pound rail was derailed, and the break looked exactly like this sample. In six months time this particular rail broke down. There is no question in our minds whatever but that this was a flaw, either a blow-hole or a crack, a very well-defined flaw, in the steel when furnished to us. The heavier traffic of to-day develops and enlarges such flaws more rapidly than under conditions of a few years ago. If the steel is homogeneous and good as we expect to get for the prices we pay, and after the inspection we give it, then we would not have such breaks. So it seems to me that we want more homogeneous material. How are we going to get it? That is the problem before us. If it is to change the section that is the thing to do; if it is by a slower process of manufacture that is another step to make. I think we should do all things that tend to secure more homogeneous material. If it is by cutting off more material from the top of the ingots we should by all means do it. I do not believe there is a single railroad in the United States that would fail to meet the exact cost that the mills think necessary to produce improved material. But we must bear in mind what rails are selling for elsewhere, as we don't want to be overcharged. **Mr. Churchill.**

MR. J. A. KINKEAD.—No later than day before yesterday I noticed in one of the engineering papers a statement coming from the New York Railroad Commission, showing the breakages of rails during the years 1905, 1906 and 1907, and remarking particularly that the breakages were excessive in 1907. From the New York State Commission I obtained an itemized statement, a blueprint which they issue, which was not for the year, but was for the three months of January, February and March, which constitute the greatest number of rail failures. In 1905 the total failures were 1,331; in 1906 they were 826; in 1907, 3,104. That is for the three months, January, February and March for the three years. It is rather interesting to note that the heaviest breakages occurred in the years 1905 to 1907. In the years 1905 to 1907 the greatest number of failures was reported on the main line of the Lake Shore road, between Buffalo and Cleveland, which is about as fine a track and roadbed as there is in the country. The number of failures on this line in 1905 was 227, and the next highest was on the main line eastern of the New York Central, which I believe is from Albany to New York, 204 rails. In 1905, the Lake Shore dropped down to 34, but in 1907 the number again came up to 505, and this was the banner road in point of breakages. The New York Central came next; the Eastern Division reporting 447. This information would be much more helpful in a discussion of this kind if a statement could be obtained showing the cause of the failures in the different cases. **Mr. Kinkead.**

I believe that the large number of rail failures is due to pipes which undoubtedly come through from the ingot. I have recently

Mr. Kinkead. had occasion to cut in two many hundreds of blooms weighing from 3,000 to 4,000 pounds, and sometimes as much as 4,400 pounds. These were ordinarily made one from a single ingot, and as the ingots weighed from 5,500 to 6,500 or 7,000 pounds, there generally was sufficient discard. We found that in some of the melts examined there was as high as 10 to 12 per cent. of piped metal, the pipe covering 15 to 20 per cent. of the total billet section. This proved in a way that the pipe is not only in the top of the ingot but sometimes extends well down, possibly all the way through, although in the ordinary shearing of the billet the pipe was not in evidence at all. The only way we found it was by cold sawing the billets, and then it was very evident.

Mr. Bostwick. MR. W. A. BOSTWICK.—Mr. Talbot refers in his paper to a number of tests made of open-hearth rails. If I am correct those open-hearth rails are of a chemical composition that we would not consider for an instant in this country as applicable to railroad service. The openh-earth steel that is used in England, and, in fact, the Bessemer steel that is used in England, is of a very much softer grade than has been found necessary for the railroads of this country, on account of the very heavy driving wheel loads, etc., so that I hardly think that the material to which Mr. Talbot has made reference would meet the conditions of service in this country.

Another point that has been raised here is the time elapsing between the manufacture of the heat, its recarburization and the teeming, and I should appreciate it very much if the speaker who referred to that could give me an idea as to what he would consider the proper amount of time to be consumed in the reaction.

Mr. Kenney. MR. E. F. KENNEY.—As a member of the Committee, I do not want to "knock" these specifications. Some portions of these specifications were honestly compromised; for instance, the specification as to the straightening. When I proposed that specification first I asked for three inches, and I still think that three inches is quite enough. In a recent day's rolling at one of the steel mills, we measured the camber on every rail rolled that day, and they were all within a limit of three inches. So it is very evident that with a careful manipulation of cambering steels it is not at all difficult to come within that specification of three inches. The rolling on the day I speak of, by the way, was not a well-balanced section.

I would like to say a word about this matter of section. A number of speakers have spoken here of taking the metal from the head to put it in the base. Now when you consider that probably ninety per cent. of the breakages to-day are in the head, I think it is decidedly unwise to rob that head of one particle of the metal. Unquestionably the base should be altered to promote a more even cooling of head and base, but the additional metal required for this purpose should not be taken from the head. **Mr. Kenney.**

MR. P. E. CARHART.—One of the speakers has brought out the element of time and the speed of the finishing train in rolling rails. Now, we have the same engine, the same diameter of rolls, traveling at the same speed to-day, as we had seventeen years ago. Then we obtained from 40,000 to 45,000 tons per month; now 65,000 tons per month, or over. Where is the difference. Then it took an hour and a half to change the rolls, taking out one roll at a time; now we do the same thing in twenty or thirty minutes by picking up a full set of rolls. So I might go all along the line, and cite, for the same soaking pits are used, the same converter, in short, the same lay-out, but it has been the cutting out of delays that has enabled us to get the higher tonnage. The increase has not been made by an increase of speed at any point; the increased tonnage has been due entirely to the elimination of delays. In other words, it was simply keeping our train occupied and full of steel, instead of being idle from one-half to two-thirds of the time. Even under present conditions, we are only turning out, theoretically, about 50 per cent. of what said mill is capable of producing. **Mr. Carhart.**

If you want to get a perfect rail section, keep your rolls full and keep your mill warm, and you will get a section that is as nearly ideal as it is possible to produce. If, on the other hand, you have delays, your rolls and beds become cold, and you are apt to run into conditions, such as would make it very difficult to camber rails so as to meet the requirements of your present specifications.

A great deal has been said in regard to moon-shaped breaks. I have investigated a number of cases, and find same due to an impact blow from an off-counterbalanced engine. You can measure between the two marks on the rails, and by calculation determine the diameter of the driver, and if you are well enough acquainted with the motive power on that road, you can locate the class of engine that is doing the damage. One road in particu-

Mr. Carhart. lar watches its rolling stock very carefully, and when a broken rail occurs they look over their engines. In the case to which I refer, the engine appeared to be all right, yet they found there was a flat spot on one of the drivers for a distance of 30 inches. This flat spot showed a middle ordinate of $\frac{3}{8}$ inch. This engine was put in the shop and the drivers turned true, and the rail breakage immediately ceased.

I have had occasion, recently, to compute the impact blow delivered by an off-counterbalanced engine, running at a speed of ninety miles per hour. Although it was one of the latest type of engines, yet at one point in the revolution the minimum pressure on the rail was 4,000 pounds, and at another point the maximum pressure was 57,000 pounds. This enormous pressure is distributed over an area of only about one-half square inch, hence you can see what a tremendous blow can be delivered in high-speed traffic. This is assuming that the roadbed is in perfect condition. When you take into account the irregularities of track, such as are due to the freezing of the ballast, and the rolling of the engine, due to this irregularity in track, the maximum pressure delivered by an off-counterbalanced engine must be far higher than that which I have computed, and the moon-shaped breakages are largely due to this impact blow. If it were possible for you to determine the maximum intensity of pressure in impact, as accurately as you can figure the stresses in a bridge, and give us the data, I think we could arrive at a conclusion, as to what kind of a section to design, that would meet these conditions satisfactorily

Mr. Hunt MR. HUNT.—Allow me to say a few words in reply to Mr. Carhart, as I presume he referred in some of his remarks to what I have already said. The day before yesterday I was in the office of the President of the Erie Railroad when he showed me some photographs representing certain sections of their track. Where represented by these pictures, the west-bound track is laid with 75-pound rails, while the east-bound one has 85-pound ones. He also showed me photographs of broken rails which had all been taken from the east-bound track. Most of them showed the crescent-shape breaks from the flanges which have recently become so prevalent. It will be appreciated that the same engines run both ways over this road, and examination of these crescent-shape breaks showed that they were not relative to the revolutions of the drivers, as in many cases there were three breaks within 6 feet of each other. Undoubtedly badly counterbalanced engines have injured many rails, and in that and other ways, I do not think the railway people have been entirely innocent, but it cannot be claimed that they are responsible for all of the rail failures. **Mr. Hunt.**

In regard to speed of product in the rails mills, Mr. Carhart's statement is quite true that if the mill is running smoothly, so far as product is concerned, it is an evidence that it is running well. It undoubtedly may be, so far as output is concerned, and it is also true that a mill that is so running will produce better work than if its speed were by spurts, but a dangerous condition results from the fact that all of the skilled employes of a rail mill are paid by the ton, based upon the total output of the mill during the time they are at work. Human nature is apt to be weak, and therefore danger exists that sometimes the full running of the mill may be under what can be designated as a strained condition. In other words, the quality of product is liable to be ignored for the sake of quantity.

It is a recognized fact that for the proper manipulation of steel ingots, they should remain in the soaking pits a length of time proportionate to the size of the ingots, and I think it has happened that sometimes, for the sake of keeping the rail rolls supplied with steel, pressure has been brought to bear upon those in charge of the heating, and perhaps this pressure did not have to be very severe, to ignore this question of time, and to draw the ingots from the furnaces, and pass them through the rolls in very much less than the proper time. If, for instance, 90 minutes should be taken, and the steel is drawn after it has been in the furnaces only 50 minutes, it will not be at all surprising if the resulting rails are not of the highest quality. I think it will not be hard to prove that such instances have occurred.

Mr. Mansfield Merriman.—The computations of Mr. Bland indicate that the stresses in the rails are not too high even with an allowance of 60 per cent. for impact, while the remarks of Mr. Carhart indicate that 60 per cent. is a very small allowance for impact, and I feel disposed to agree entirely with him. Even in the case of bridge members, which are much less subject to impact than railroad rails, 60 per cent. is not considered a high allowance. Upon the rail there is all the increased effect of suddenness of application and also other stresses due to vertical oscillations of **Mr. Merriman.**

Mr. Merriman. the load. We need only to recall the beautiful experiment made by Professor Goss, in which a wire was run underneath a driving wheel, a portion of the wire being crushed and another portion not; indicating that the entire wheel had been elevated by an improper counterbalance. Now, while the stress of 8,000 or 10,000 pounds per square inch for a span of 24 inches, with a 100-pound rail, as indicated by Mr. Bland, is about right, this figure is for the static load. But if the wheel load of 25,000 or 30,000 pounds be supposed to drop through the small height of $\frac{1}{20}$ of an inch, my computations indicate that the static stress is multiplied by 7 or by 8, so that the true stress instead of being 8,000, is over 50,000 pounds per square inch. It may also be expected that such high dynamic stresses, due to irregularities of track and to imperfect counterbalancing, will prevail in the future as they have in the past

Another point, which has not been spoken of and which I have not seen referred to in literature, is that of the action of the splice bars. The two splice bars on the opposite sides of the rail are connected by bolts while between each splice bar and the web of the rail there is a space of half an inch or more. The consequence is that when the bolts are screwed up tightly, there acts upward upon the head of the rail a force which tends to tear the head from the web, and also each side of the head is brought into action like a cantilever beam. My computations indicate that the upward pressure that can easily be exerted by screwing up the bolts is sufficient to cause a tensile stress of some 15,000 pounds per square inch stress in the web. Simultaneously also, there is produced at right angles to the web a flexural stress of 8,000 or 10,000 pounds per square inch. These two stresses act upon the unloaded rail in the fillet joining the web and rail head, and there is also a third flexural stress produced by the wheel loads. Hence there may exist three stresses in the fillet at right angles to each other, two of them tensile and one compressive, or sometimes all three may be tensile. It appears, therefore, that the action of these splice bars, when screwed up tightly, is such as to give a partial explanation of the fact that there are many breakages at the ends of the rail. Imagine those two constant tensile stresses that I have indicated, together with the alternate one, due to the passage of the train, and it is not difficult to understand that detail fracture will begin in the fillet and perhaps increase sufficiently to be the cause of rupture. **Mr. Merriman**

The remedy for the present breakages of rails, as far as I have been able to study it, does not lie in altering the shape of the rail, for it seems to me that the present proportions are good ones. One remedy would be to put the cross-ties nearer together, thus reducing the span. Perhaps another remedy would be to make the splice bars thicker, so that they would almost touch the web of the rail; thus the leverage of the vertical force against the lower side of the head of the rail would be decreased, and the initial stresses in the web and head of the rail, due to screwing up the bolts, would be rendered smaller.

Mr. Trimble MR. R. TRIMBLE.—When I accepted the Secretary's invitation to come to this meeting and take part in the discussion of this question, I told him that I did not expect to say anything, but I would like to say to Professor Merriman that we do not have the trouble that he speaks of with splice bars. That is not where the rail breaks. We did have trouble there, but our trouble has been for quite a number of years entirely away from the splice bars. The breaks in rail occur 4, 8, 10 or 12 feet away from the joints. Out of 100 rails that were removed on a certain piece of railroad recently, my recollection is that not one broke at the splice.

Mr. Thackray MR. G. E. THACKRAY.—Mr. Chairman, replying to the remarks of the last speaker, and adding my voice to that of Professor Merriman regarding the question of the unit stress which exists in a rail, you know that rails are not statically loaded. A unit stress of 8,800 pounds per square inch, as stated to exist under the wheel loads on a 100-pound rail, including an allowance of 60 per cent. for impact, is, I think, really too small; as against which actual tests of rails in use show that this stress is 40,000 or 50,000 pounds per square inch, under conditions as measured, not to say how much more it is under other and unmeasured conditions. We also know that when rail material which stands 120,000 pounds per square inch is broken in use, a theory of the stresses dependent on static loading is of no value whatsoever.

Regarding the question of the longer life of the lighter sections of rails, while there may be some reason for their longer wear owing to their flexibility, to a certain extent, there is another and better reason, in my opinion, and it is this: that they are rails which by

Mr. Thackray. course of trial and selection have stood the test of time under comparatively light traffic and loads. The bad ones of that size have been broken or worn out and have gone; and those that remain are the better ones, and naturally they will continue as against some of a new set which has some bad ones in it, and the new and the old are not exactly on a parallel for that reason.

Mr. Churchill has told us, and with truth, that the matter of increase of the section of the rail is something which comes about very slowly and very gradually. Mr. Wille again has told us that in the last twenty years the wheel loads have increased three times or more. In some cases that have been stated to us the weight of the rail has only been increased by ten or fifteen pounds per yard as against an increase of three times in the wheel loads. We must admit, that in their desire for tonnage, for large and paying traffic, the railroads have increased the size and weight of cars, they have increased the size and weight of locomotives, the tonnages have grown wonderfully and the speed of trains almost doubled, while at the same time they have allowed the weight of their rails to lag behind and have not increased their sizes and strengths to the standard of present day requirements. Please understand that the foregoing is not said in a contentious spirit, and I wish to add that the rail makers are doing their utmost and will continue to do everything that is possible towards the betterment of rail quality, dependent, of course, on limited conditions. As to the question of specifications that was introduced by the chairman of our committee, I think, perhaps, you all know that these have only been arrived at by some years of study and argument, and it is only very recently that they have got into their present fairly satisfactory condition. We are all striving for ideals, and would like to have the best rail specifications just as we all hope to be angels some day, but the ideal specifications can only be approximated and certainly none of us want to be angels for some time to come.

MR. THACKRAY.—Mr. President, a short time ago I was at a station waiting for a train that was a little late, and one of the maintenance-of-way men came in, and he explained the delay by stating that some of the men on a freight train which passed recently had neglected to unset the brakes on one of the cars, with the result that one car was skidding, and actually fused a portion of one of the wheels, that is, melted it down on part of the tread and flanges. May I ask from railroad men if occurrences of that kind are frequent? **Mr. Thackray.**

THE PRESIDENT.—Flat spots are frequently produced in that way. **The President.**

MR. THACKRAY.—Yes, but my informant explained that a portion of the wheel was actually fused and melted away, so as to produce a wreck. **Mr. Thackray.**

THE PRESIDENT.—I don't know of any wrecks produced that way, but flat spots are often caused by sliding. **The President.**

MR. KENNEY.—I want to reply to Mr. Thackray. He neglected one point. He said the railroads had increased the sizes of engines, cars and all their equipments, but had let the weight of rails lag behind. He has forgotten just one point to make it complete and that point is the fact that the mills have bettered the quality of the metal furnished for the engines, cars and in fact nearly everything else, but the quality of the metal in the rails lags behind. As a result we get to-day in rails a grade of metal that has been discarded for nearly every other use. **Mr. Kenney.**

MR. THACKRAY.—I wish to take issue with the gentleman by stating my belief that the chilled wheels which the majority of the roads use to-day are not as good as they were years ago when charcoal iron alone was used. **Mr. Thackray.**

MR. M. H. WICKHORST.—I should like to say something on the question of these moon-shaped brakes. On the Chicago, Burlington and Quincy, during the last winter, on a piece of track about three miles long, and in a period of a very few weeks, as many as fifty of these breaks occurred, and I submit herewith a copy of my report concerning this cause: **Mr. Wickhorst**

AURORA, ILL., June 5, 1907.

MR. A. W. NEWTON,
Inspector, Permanent Way and Structures, Chicago, Illinois.

Dear Sir:—

I give below report covering tests we have made of eight samples of rails which broke in the track last winter west of Oregon, Ill. These were Illinois Steel Company 85-pound rails laid last fall, 1906 rolling—months of August, September and October. The failures occurred mostly during very cold weather last January and February, and the examination which was made by yourself, Mr. Ustick and myself on the ground showed the failures to consist of crescent-shaped pieces broken out of the base of the rail, followed in good many cases by breaking through the whole section

Mr. Wickhorst. of the rail. There were in all about fifty failures most of which occurred in the mile west of mile post No. 104. The piece of track along here has a heavy down grade eastward. Mr. Ustick had a number of these rails sent to Aurora and I selected for laboratory examination, eight samples which were broken through the whole section, and to show the nature of the break, I enclose laboratory photograph No. 185 (Fig. 1), showing pieces from five different rails. The two pieces showing the under side of rail are from different rails, while the other six pieces are pairs from the other three rails.

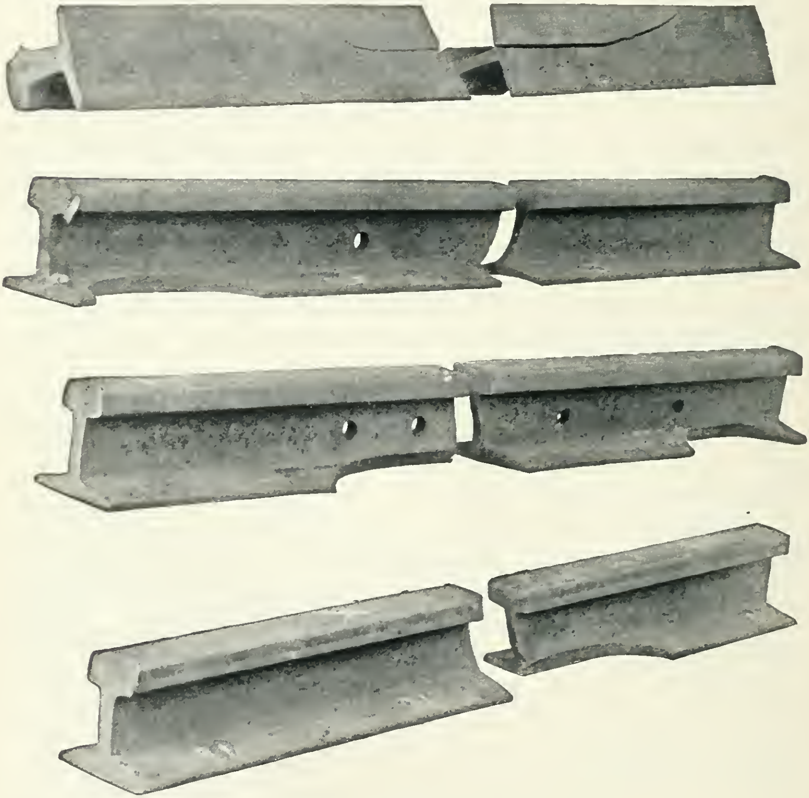

FIG. 1.

Etching.—To show up whether there was any piping or porosity of the structure, I arranged to have sections taken near the point of failure, which sections were polished and etched with acid. I enclose laboratory photograph No. 186 of these etched sections from which you will note that no piping whatever was shown up, and the eight samples all show a sound structure, except that sample No. 3 showed a condition of sponginess.

Mr. Wickhorst.

Analysis.—We have made analyses of samples taken from the heads of these rails, results given in the table below, and for comparison I also give below the requirements of the American Railway Engineering and Maintenance of Way Association which are the same as the requirements of the American Society of Testing Materials.

ANALYSIS OF STEEL RAILS.

	1	2	3	4	5	6	7	8	Specification A.R.E.& M.W
Carbon......	.52	.480	.52	.490	.510	.540	.520	.510	.43 to .53
Phosphorus	.09	.092	.104	.099	.096	.101	.100	.100	.10 maximum
Sulphur....	.06	.043	.048	.049	.039	.064	.029	.040	
Manganese.	.98	.930	1.000	.900	.850	.900	.950	1.150	.80 to 1.10

These rails meet the standard chemical requirements except in a few instances where the variations from the standard requirements are not great.

Tensile Test.—We have made tensile test of samples machined from the head of the rail using standard test pieces of 2-inch gauge length, ½-inch diameter; test pieces being taken from the middle of the head. For comparison, we also arranged to take short pieces from the head, heat them and hammer them down to about one inch in diameter. Similar test pieces were then machined from these hammered-down bars, and I give below a table showing results on both the original material and hammered-down material:

		Tensile Strength. Lbs. per sq. in.	Elongation. Per cent.	Reduction in area. Per cent.
No. 1	Original..................	100,290	20.5	35.5
"	Hammered down.........	100,484	20.3	31.0
No. 2	Original..................	99,600	21.5	35.5
"	Hammered down.........	103,195	20.3	35.3
No. 3	Original..................	108,350	17.5	27.7
"	Hammered down.........	110,983	19.5	39.1
No. 4	Original..................	100,500	20.0	32.8
"	Hammered down.........	100,249	23.4	35.4
No. 5	Original..................	112,300	11.0	11.9
"	Hammered down.........	106,340	21.8	39.1
No. 6	Original..................	106,760	19.5	30.8
"	Hammered down.........	107,788	21.1	37.2
No. 7	Original..................	100,090	16.0	....
"	Hammered down.........	118,572	14.1	14.2
No. 8.	Original..................	116,710	4.0	24.9
"	Hammered down.........	120 913	21.1	39.1

Mr. Wickhorst. It will be noted that in the original samples in some of the cases, the elongation and reduction of area were low. The effect of reworking was in general to leave the tensile strength about the same, but to materially increase the elongation and reduction of area where these properties were low in the original material. Where the original material already showed a good elongation and reduction of area, the reworking did not improve

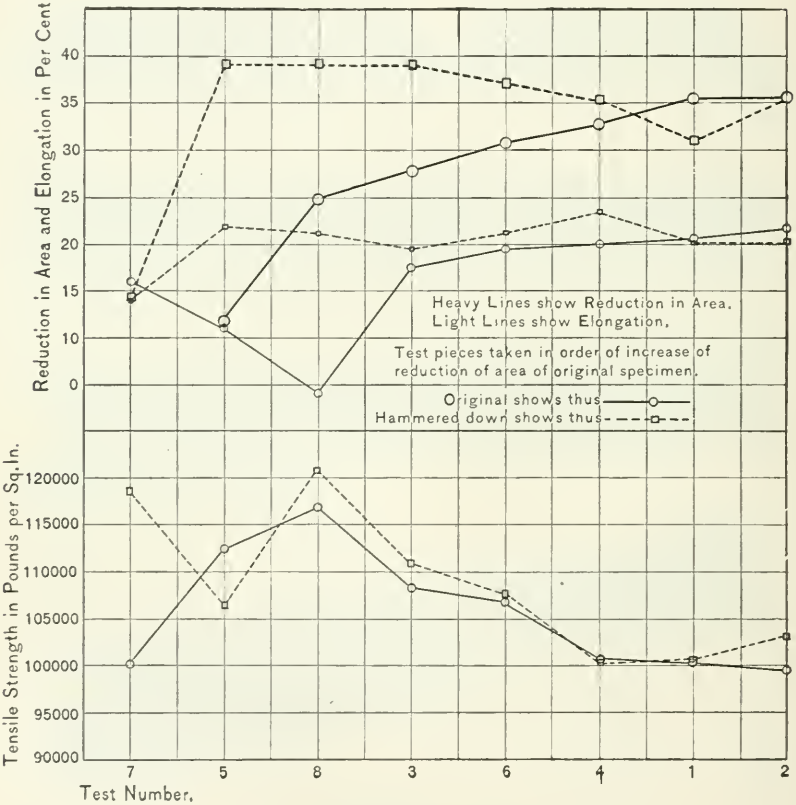

FIG. 2.

these qualities, and in cases of samples Nos. 1 and 2, they actually decreased. Sample No. 7 showed up badly in both the original and hammered-down samples. I enclose blue print Laboratory No. 626, 143-R-4 (Fig. 2) giving results of the tests graphically to show the relationship somewhat more clearly. These tests seem to show clearly that five out of the eight rails could be materially improved by further work. It would also seem that a suitable annealing process where the material is brought up to a red heat and allowed to cool would bring about somewhat similar results, and I hope some time to make some tests of this nature. **Mr. Wickhorst.**

Track.—Our examination of the failures on the ground seem to show without doubt that primary failures consisted of a piece of the base of the rail breaking out and that the breaks through the whole section were secondary or resultant failures. One noticeable feature was, that in almost all cases the inside flange of the base broke out and they also occurred mostly on the north rail. This piece of track has heavy grade downward toward the east, that is, the direction of fast speed would be eastward and failures therefore would be mostly on the left-hand rail in the direction of fast speed. I give below copy of your letter of March 23, 1907, showing a classified statement of the rails broken:

MR. MAX H. WICKHORST, CHICAGO, March 23, 1907.
Engineer of Tests, Aurora.

Dear Sir.—

At your request, I hand you herewith statement of broken rails inspected west of Oregon:

Location and Conditions.—Mile 104 between Oregon and Stratford, ascending grade, west bound, gravel ballast—all rails on tangent except two.

Breaks on North Rail.—A. On inside flange on soft wood tie with metal plate, there being oak ties on each side of soft wood tie. Twenty failed rails, two of which were on curve.

B. On outside flange on hardwood tie without metal tie plate. One failed rail.

Breaks on South Rail.—A. On outside flange on hardwood tie without tie plate. Two failed rails.

B. On inside flange on soft wood tie with metal tie plate, there being oak ties on each side of soft wood tie. Seven failed rails.

Yours truly,
(Signed) A. W. NEWTON.

The ties on this part of the road are mostly oak ties, but quite a number of oak ties have been replaced by soft wood ties with an iron tie plate, the tie plate being absent in the case of the oak ties. As shown by your statement, the most of the cases of flange breakage occur on a tie plate with soft ties.

Counterbalance.—The failures occurring mostly on the left rail eastward, suggested that the locomotive counterbalance had some influence in the matter, and I talked with Mr. O. W. Ott, of Mechanical Engineer's Office, who has done some work along this line. I give below a copy of his letter of March 22, 1907, together with blue print which he submitted, which I think you will find interesting:

Mr. Wickhorst.

CHICAGO, ILL., March 22, 1907.

MR. M. H. WICKHORST,
Engineer of Tests, Aurora.

Dear Sir:—

With regard to the cause of broken lower flanges occurring at the tie plate, on the north rail of the Aurora to Savanna track just west of mile post No. 104.

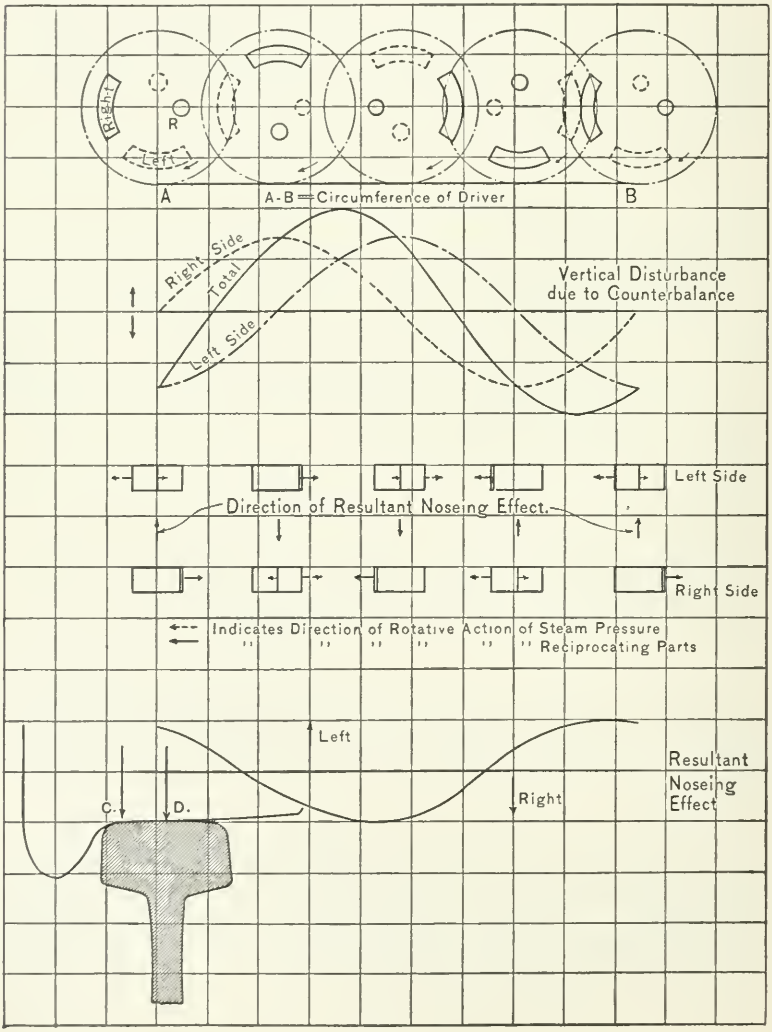
Right
R
Left
A
A-B = Circumference of Driver
B
Right Side
Total
Left Side
Vertical Disturbance due to Counterbalance
Left Side
Direction of Resultant Noseing Effect.
Right Side
Indicates Direction of Rotative Action of Steam Pressure
" " " " " " Reciprocating Parts
Left
Right
C.
D.
Resultant Noseing Effect

FIG. 3.

Between mile posts 104 and 105 the grade is .8 per cent. with the down grade east bound. Also the ruling grade from Polo to Oregon is down hill and quite heavy so that there is little doubt that east-bound trains attain a very high speed between mile posts 104 and 105. **Mr. Wickhorst.**

Attached is a blue print (Fig. 3) showing the effect of the counterbalance of the locomotive drivers. At the top of the sheet is a series of circles showing the location of the crank pins and counterbalance boxes on a pair of driving wheels during one complete revolution, the points illustrated being for each 90°. Next below you will note three curves plotted to show the vertical disturbance due to the excess weight placed in the counterbalance boxes to partially balance the horizontal disturbance of the reciprocating parts.

In the center of the sheet are some small cylinder diagrams laid out to show the horizontal disturbances which cause the engine to nose. Nosing is caused by two forces: The reaction of the steam pressure against the cylinder heads and the horizontal inertia of the unbalanced portion of the reciprocating parts. Just below the small cylinder diagrams is a graphical curve showing the resultant force causing nosing.

At the lower left-hand corner of the sheet is a section of an 85-pound rail with a driving wheel superimposed. I believe that the fact that the majority of breakages occur on the north rail can be accounted for as follows: You will note that when the hammer blow on the rail is a maximum the engine is nosing strongly to the left, or over against the north rail on east-bound trains. The effect of this nosing would be to cause the wheel flanges on the left-hand wheels to climb the rail and thus the point of application of the load between the rail and the wheel would be shifted from a normal position close to the rail center at D to a point close to C. Then we have the rail eccentrically loaded at the same instant that it is called on to sustain the added pressure due to the hammer blow of the counterbalance. Without iron tie plates the effect of the eccentric load would be equalized by the yielding of the tie and thus distributed equally to the inner and outer portions of the bottom flange of the rail. With iron tie plates the ability of the rail to adjust itself to the eccentric load is minus, and the inside bottom flange of the rail will get the large end of the load.

An R-4 engine running at a rate of speed equal to the diameter of the drivers, or 69 miles an hour, will give a so-called hammer blow of 11,200 pounds on the front and rear drivers and 13,900 pounds on the main drivers. This gives wheel loads of 34,550, 37,200 and 40,050 pounds, respectively.

These loads being applied eccentrically once every revolution to the left-hand rails is the probable cause of the rail failures.

Yours truly,

(Signed) O. W. OTT.

According to his study and diagram, it is shown that when the effect of the counterbalance is greatest downward, the engine also noses to the

Mr. Wickhorst. left. This would tend to make the fillet of the wheel flange put the load on the inside edge of the rail head, which in turn would put the load on the inside flange of the rail. This apparently accounts for the greater number of breakages of the inside flange of the rail, and also the greater number of breakages on the north or left-hand rail in the direction of high speed.

Conclusions.—As a result of our investigation, I should say that these rail failures are due to a combination of circumstances. Firstly, we have seen that while rails are sound, about 50 per cent., or perhaps more, showed low ductility on a tensile test, that is, the elongation and reduction of area were low; in some of the cases very low. Secondly, failures occurred during very cold weather when the track was frozen very stiff, and occurred mostly on soft wood ties with tie plates having on each side oak ties without tie plates. The effect of the tie plates apparently was to form a very rigid unyielding spot that probably took an undue proportion of the blow of the rolling equipment. The very low temperature also probably rendered the material more brittle. This experience indicates that it is not wise to have ties with tie plates interspersed with ties without tie plates. Thirdly, the impact effect of the heavy counterbalance required in the large engines apparently added just sufficient impact effect to cause failure. Yours truly,

M. H. WICKHORST.

Mr. Fowler. MR. W. E. FOWLER.—I wish to take exception to a statement made by one of the speakers which gives a wrong impression in regard to the effect of brakes on the rails. I wish to say that it is considered very bad practice to have wheels skid or slide in stopping a train. It is a well-established fact also that a train can be stopped in very much less distance when the wheels are not skidded, when the rotation of the wheel is gradually retarded. And I think it will be found a very rare occurrence—for us it is—when the wheels do skid. I wish to go further than that, and say that in an experience of a good many years I have never yet seen a wheel that was melted down by skidding in service. We occasionally have skids on wheels five or six inches long, but never yet have I found (through an extended experience in mountain districts) a wheel melted down by the action of the brakes in skidding the wheels. The cast-iron wheel is considered better as now made than fifteen or twenty years ago. That is also an established fact. The test to which cast-iron wheels are subjected before service is very much more severe than was considered possible fifteen or twenty years ago. One of the regular tests is to lay the wheel, flange down, in the sand and then encircle it with a ring of molten metal, which subjects it to a very much more severe strain than any of them receive after they are put in service. The ordinary service of the cast-iron wheel is very much more severe to-day than it was fifteen years ago. The loads which are carried upon it are very much heavier, and the speed at which it revolves is very much greater. Although I do not think there is a cast-iron wheel manufacturer here this afternoon, I do not think it right that the statement that the cast-iron wheel is damaging the rail in the way described, should go on record as the opinion of this convention. **Mr. Fowler.**

MR. J. P. SNOW.—I wish to add a little testimony in regard to the crescent or moon-shaped breaks that have been spoken of. My experience has been exactly in line with Mr. Wickhorst's, and the results of the tests that we have been able to make correspond with his. There is one feature, however, that I have observed in connection with these crescent-shaped breaks that has not been spoken of, which I should like to lay before the meeting. **Mr. Snow.**

In all of this type of breaks that I have observed, I have found it possible to detect the evidence of a longitudinal seam in the base of the rail which appears to be the starting point of the fracture. The edge on the under side of the piece that breaks off is smooth on the corner for a short distance; sometimes, however, if the break is a long one this smooth corner will extend for a foot or more. From the ends of the smooth corner the break bursts out to the edge of the base in a curve similar to the regular conchoidal fracture of homogeneous material. These smooth corners are evidence of seams existing in the rail before the break occurred. Whether these are caused by a buckle or lap, as suggested by Captain Hunt, or are the result of gas checks in the ingot I do not know. Some of these seams are open enough to be discolored by rust; others are so tightly closed that rusting has not commenced. Examined with a magnifier the seams appear striated and show plainly that they are not fractures.

A sample cut out of one of the broken pieces, when examined with a microscope, showed a very large number of slight microscopical cracks parallel to the axis of the rail, and with their planes vertical in the flange. These seams must be due to the condition of the ingot before it is rolled, or are caused by the rolling.

In regard to these breaks being caused by unbalanced drivers: It is quite likely true to some extent, but those unbalanced drivers

Mr. Snow.

go over miles of road and do not break all the rails. It is only the unsound rails that break. Now if you take one of those rails with a crescent-shaped break, as we have, and turn it on its head and let a man strike the flange with an ordinary sledge he can break out these crescent-shaped pieces just as fast as he can hit the rail; a rail that has broken from some other cause, or a good rail, that is not broken at all, can be turned on its head and pounded until you are out of wind, and you can't break a piece out.

Most of the rails that have completely broken in recent years with us, have apparently started from a seam in the base and burst out to both edges of the base in a conchoidal curve leaving a cusp point on one piece of the broken rail. Split heads complained of by roads with heavy traffic are quite likely due to seams in the head similar to those which we have observed in the base. If these seams, which I believe to be due to unwelded gas holes in the ingot, can be avoided I think much of the trouble from unsound rails will be overcome.

Mr. Wickhorst.

MR. WICKHORST.—Mr. Snow looks for these seams after he finds a crescent-shaped piece ready to break, and of course he finds them; because the effect of the stress is to start a crack right in the middle of the base of the rail. That is where the stress would be greatest, or in that neighborhood, and it is not the first application, but a great number, that results in failure. It is a case of failure in detail. Of course if you find that the crescent-shaped piece has started to break out, you will always find a vertical seam, and it will show from its looks that it has been there some time, naturally.

I move that the specification as proposed be accepted by the meeting and submitted to the Society by letter-ballot.

The President.

THE PRESIDENT.—Before putting the question, may I be allowed just a word. Naturally the consumers, or the railroad people, think the principal fault in the breakage of rails is due to the poor rail; and just as naturally the producers think that the principal fault is in the conditions of service. It has been agreed apparently all around, and there is no doubt about the data, that wheel loads and speeds have increased; and it is also true that sections have been increased, the amount of metal put in to sustain the load and meet the service conditions has been increased; and yet if we can trust the data, we are having breakages that are serious. Now the question is, how are we going to get a better rail? Modifications of the section have been proposed and there are a number of points in the constitutions of the steel itself that have not been brought out at all: notably, the amount of discard from the ingot and the segregation which necessarily takes place in the big ingots. **The President.**

[Mr. Wickhorst's motion that the specifications reported by the Committee be submitted to letter-ballot of the Society, was duly seconded and carried by more than a two-thirds vote.]

Mr. Forsyth. Mr. William Forsyth (by letter).—I will discuss the breakage of steel rails with special reference to the impact due to heavy wheel loads and high speeds. The paper by Mr. Wille gives data relating to the increase in the weight on drivers of locomotives and shows that it has increased 85 per cent. in the past ten years. The load on a single driving wheel is now frequently as high as 30,000 pounds, and the centrifugal effect of the counterbalance in unbalanced engines may increase this static load by one-third, making a maximum load of 40,000 pounds per wheel at high speed. The ordinary assumption of 100 per cent. addition for impact due to live load is not sufficient, as it can be shown mathematically that the force of impact increases as the square of the velocity. This demonstration with special reference to the stress in rails will be found in a paper by Mr. Mattes at a Scranton meeting of the American Association of Mining Engineers.

The magnitude of the stress in rails with a static wheel load of 40,000 pounds may be nine times as great at 75 miles per hour as at 25 miles per hour, and light rails which do not break under the heaviest locomotives at ordinary freight speeds, would not be safe on level roads where the speed of passenger engines is high. The report of the New York Railroad Commission shows a large number of broken rails for the winter months on the Lake Shore and New York Central Railroads, and it is on these lines that the high speed 18- and 20-hour train schedules are maintained winter and summer.

The principal cause of rail breakage on these lines is largely due to heavy wheel loads acting at high velocities. Where the track is heaved by frost and very rigid, as it must be in zero weather, and the rail is not in perfect surface, it is subject to the severe impact above described, and the irregularity in surface may be sufficient to result in stresses greater than the resistance of 100-pound

Mr. Forsyth. rails made of good steel. My suggestion, therefore, is that in designing a new rail section for modern high-speed locomotives, the ordinary effect of impact as assumed by bridge engineers does not take account of the real effect of high velocities, and a rail section should be used, which will not show a high unit stress when subjected to the impact of the heavy wheel load at speeds of 80 or 90 miles per hour.

NOTE.—It is proposed to continue the discussion on Steel Rails at the next annual meeting, and members are invited to send written discussions on the foregoing matter to the Secretary. —ED.

REPORT OF COMMITTEE C ON STANDARD SPECIFICATIONS FOR CEMENT.

The Committee at its meeting held in Philadelphia on June 4, 1907, decided that it was not prepared to present any further report, or to suggest any changes in the specifications for cement, for the present year. The Committee has the question of changes under consideration and therefore asks for its continuance.

Respectfully submitted on behalf of the Committee,

George F. Swain,
Chairman.

Richard L. Humphrey,
Secretary.

DISCUSSION.

The Chairman. THE CHAIRMAN (Mr. Robert W. Lesley).—I think it would be very interesting at this time, probably, as this specification stands as one of the extremely successful specifications of this Society, to give a little idea of what has really been accomplished in this matter, and a little of the purposes that have governed the Committee in its action. About three years ago there was really no uniform specification of cement or methods of manipulation. There had been suggestions; but nothing had ever been accomplished; and, as we all know, the woods were as full as the leaves of Vallombrosa of specifications of all kinds that were blowing hither and thither.

This Society, in co-operation with representatives of the railroads and the architects, and the American Society of Civil Engineers and the cement manufacturers did make a specification; and that specification has been in use some two years, or two years and a half. Over 40,000 copies of that specification have been sent out, mostly upon request, to all parts of the civilized world, which certainly speaks well for the care and the thought that were given to its making.

This specification was made to meet the views of the conservative people on all sides of this question. It should be remembered, too, that while it is the policy of this Society to accord equal representation on all committees dealing with commercial matters to the manufacturers and the consumers, this Committee consisted of about eight manufacturers and twenty representatives of the consumers; so that the latter were in a majority of two to one; which I think speaks for the fairness and broad-mindedness that have served to make this a real living specification.

Now, as a result, the American Railway Engineering and Maintenance of Way Association have adopted this specification for practically all of the work of the railroads. A year ago the Government, through the Panama Canal Commission, undertook to make a specification for cement; they changed it about two or

The Chairman.

three times; and within the past year our specification has been adopted for the important work of the Panama Canal, and I am informed that the specification is also in course of adoption by many of the departments of the United States Government.

In short, it is a well-known fact that this specification is being widely adopted, and while we all realize that there are some things that should be corrected, it should be remembered that there are always things that should be corrected in any specification.

The American Society of Civil Engineers through their committee is working on modifications of the methods of testing cement. As the work of our Committee was based upon the methods of testing of the American Society, and as the members of their committee are members of our Committee, it certainly would not be wise to make changes in the specification until the committee of the American Society of Civil Engineers on methods of manipulation has made its report. Further than that, in view of the great difficulty of securing the adoption of this specification as universally as it has been and the necessary confidence that the people who adopted it feel in it, it was deemed, at a meeting of the Committee the other day, that with all due deference to the suggestions that had been made, the first thing was to get the consumers at large to know what this specification is, and what uniform specification means to them; after that, we should invite others to join in the deliberations of this Committee, increase the membership and take into consideration everything that any one had to propose. It was thought best to wait and modify the specifications at a time when we would not stand in the position of stultification by quick changes of face. Let us, at least, give this specification time to sink into the minds of the public; time to grow, as it has grown; and let us continue our Committee.

I understand in a general way that there has been some talk of reform, but it seems to me that the best method of reform in a body of this kind is, as in political reform, a reform within the party. I feel that if there be any question about this specification, or if there are those who have other ideas in connection with this specification, that they will consider that all reforms should be reforms made within the party, and that the party in this instance is a sane and not a sporadic, temporary thing, and not to be changed with every gale.

Mr. Humphrey.

MR. RICHARD L. HUMPHREY.—I have no doubt that many members of the Society feel that the Committee on Standard Specifications for Cement has been doing nothing since it presented a report; that it has simply let matters drift along, being satisfied with the work which it has already done, instead of changing the specifications, as many of the members think should be done.

One of the most difficult things to accomplish is the adoption of a standard specification of any kind, because every member of a committee having such work in hand feels that his own ideas, or his own specifications, are the best, and the larger the committee the greater is the difficulty of evolving a specification which can be adopted. It is only by giving and taking that the various ideas are brought together in a single specification. The present Standard Specification for Cement is the result of such a process.

It is admitted by every member of the Committee that the specification is not perfect, and that eventually it must be changed, but in the absence of something better to substitute for the present specifications, it seems unwise to make any changes. A number of trivial changes might be agreed on, which, if adopted, would tend to throw a doubt on the whole specification. The specification has been circulated extensively, and is being used. After one or two years of use the defects, if any, will become more apparent, and it will be more easy to apply definite remedies.

The members of this Society should bear in mind that the Committee on Standard Specifications for Cement is busy. It is working in close sympathy with the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, and at the proper time it will make conservative changes based on good reliable information which will justify such changes.

Surely a Committee which has been engaged in framing standard specifications for seven or eight years is in a far better position to know the requirements of such a specification, and to pass judgment on the proposed changes, than men who have perhaps not had as long or as intimate an experience in the question of framing a standard specification.

The Committee on Standard Specifications for Cement at all times invites suggestions, and those members of the Society not on the Committee who feel that the specifications should be changed should communicate such suggestions to the Committee, who will carefully consider them to the fullest extent. The Committee is extremely anxious to receive criticism since it enables the Committee to see the specifications from other points of view, and in this way receives valuable help. **Mr. Humphrey.**

MR. C. F. MCKENNA.—When these specifications were about to be voted upon at our meeting here three years ago, I moved that they be referred back to the Committee for further consideration and amendment. It was then declared to be quite easy to amend the specifications at any time, and my motion was lost. It is now declared, on the contrary, that we should go very slowly about amending them, for among other reasons the United States Government has just accepted them and we ought not to admit so soon that they need amendment. **Mr. McKenna.**

It is exceedingly difficult to bring about a good number of meetings of this Committee and a good discussion of the subjects. The number held since 1904 has been utterly inadequate. I submit that the opportunity for discussion of the features of these specifications is best presented at these annual meetings, but that the rules of procedure prevent us from discussing them; and that the opportunities for discussing them during the year have been in the past so rare that there is very little hope of even a single change being brought about unless there is more energy and more activity in the promotion of frequent meetings of the Committee.

MR. HUMPHREY.—Mr. McKenna is quite correct in his statement as to the number of meetings which have been held; but it should be stated further that there has been a great deal of correspondence relative to changes in the specifications among the members of the Committee with a view of crystallizing the views of the members. It is extremely difficult to get so large a body of men as compose the Committee on Standard Specifications for Cement to meet frequently, and it seems extremely desirable to carry on a great deal of the preliminary work by correspondence. After the views of the members have been gotten into tangible shape by correspondence, a meeting of the Committee is called. Such a meeting was called in May of the present year, and even then it was found extremely difficult to fix a date which would be satisfactory to a majority of the members of the Committee who attended this meeting. **Mr. Humphrey.**

THE CHAIRMAN.—I think it is perfectly clear that if any mem- **The Chairman.**

The Chairman. bers desire a meeting of this committee, a request for such a meeting should be addressed to the Chairman or Secretary.

We certainly want to work on the lines of least resistance and greatest co-operation. If it is believed that a number of meetings will bring about valuable results the Chairman of this Committee will be only too glad, I am sure, to have all the meetings desired. I think that is a very easy matter to decide; but I do feel, that while we have been going on gradually in getting these specifications adopted, that that has been a very big piece of work. After they are adopted—and they have now been adopted practically everywhere—I, for one, would be only too glad to attend meetings of the Committee as often as necessary to consider any suggestions for their improvement. We all want to avail ourselves of this Society of ours as a clearing-house for specifications; and let us make any changes, and do what we are going to do, within the lines of this Society, which stands preeminent in this particular field.

Mr. Walter. Mr. L. W. Walter.—I am very glad to hear an expression from members of the Society, and particularly from members of Committee C, to the effect that they anticipate making changes in the specifications, or, rather that they expect the Committee of the American Society of Civil Engineers to take some action, and they, thereafter, will co-operate with them.

I have been of the opinion for some time that the specifications are faulty. In fact, I don't mind going on record as saying that the cement specifications must be changed, and eventually will be changed. Now, with that in view, the Committee is morally responsible to the Society for action, and I think it is the duty of this Committee, whether it be in co-operating with other societies through a joint committee, or in whatever manner they see best, to carry out the desired end. I think activity is what we need, and that not only the Society but also the public demands.

The fact that forty or fifty or sixty thousand copies of the specifications have been sent out does not justify the Committee or the members of the Society in continually defending the specifications when they are not what they should be nor what they eventually must be.

Mr. Webster. Mr. George S. Webster.—Prior to the meeting of the Committee in Philadelphia a few weeks ago, communications were sent

Mr. Webster. to all members requesting them to offer criticisms of the specifications. At the meeting all the replies were carefully considered and all the points gone over and thrashed out; the opinion of the members present was almost unanimous that it would be unwise at this time to make any changes.

And I feel that the changes that are suggested in the specifications should not be broadly termed changes. They are improvements. We, like others, are progressive, and the time will come, and is coming, when we will make specifications to meet these advanced ideas. It did not seem to the Committee, however, that the time was yet ripe, therefore we made this report to the Society.

Mr. Walter. MR. WALTER.—I am pleased to accept the term "improvement" as preferable to "change." But the Committee has now been continued for three years without effecting any improvement; and it seems that to encourage the consumers to adopt the present specifications when we believe that they are not perfect and that there is room for improvement, would mean to entice them to accepting something through ignorance of the actual conditions, by soliciting their faith in something in which we do not have the utmost confidence.

Mr. Greenman. MR. R. S. GREENMAN.—Just a word in reference to the present specifications, as we found them when we considered them three years ago in connection with specifications for our Barge Canal work. That you may know whom I represent: I am connected with the laboratory of the New York State Engineering Department. The State of New York is about in the actual beginning of construction of a large canal which, in point of material, is to be greater than the Panama Canal. The appropriation for that was $101,000,000. We are also building $50,000,000 worth of good roads, and the state is putting up a large number of state buildings, for all of which we test the cement. In 1904, when the Barge Canal Advisory Board wanted to have specifications drawn up for their Barge Canal, I was authorized to draw up the specifications and present them to the Board; and when I presented the specifications practically as they are now, the Advisory Board questioned me for a long time, first, as to this Society, what it is, and then regarding the specifications. They found that the methods of manipulation could be questioned more than could the specifications; and when they adopted the recommendation of the speaker it was with this

Mr. Greenman. idea: that rather than to say the tests should be made according to the methods recommended by the Committee of the American Society of Civil Engineers (of which each member of the Commission was a member), they cut that out; but they followed the specifications, except in one or two minor points, almost to the letter; and we have found them to work very well. There are one or two suggestions we would like to make to the Committee some time; but, as a whole, I think they work well, and secure for us, as a large user of cement, a very good product for our work.

Mr. Humphrey. MR. HUMPHREY.—I think from Mr. Walter's discussion of the present Standard Specifications for Cement it would be natural to infer that they were pretty poor, and while it is realized that Mr. Walters has had many years of experience in testing cement, it should not be forgotten that there are many more members who have had far greater experience, and I want to say that those members approve of these specifications for cement, feeling that they are immeasurably better than anything that existed heretofore, and while not perfect, nevertheless they can be used with the assurance that any cement that meets their requirements is of first-class quality and meets all the practical conditions.

Many of the changes that are proposed by certain members of this Society are trivial in character and do not effect in any way the essential features of the specification. If the members who feel that the specifications should be changed will communicate with the Committee stating the changes desired in a definite way, the Committee can then act on them, and should the suggestions be of value, adopt them.

The Committee on Uniform Tests of Cement of the American Society of Civil Engineers is now engaged in making investigations of the question of uniform methods for testing, which form a basis of the present standard specifications. When this Committee presents its report, which it is expected to do next January, the Specifications Committee can then act, and make such changes in the specifications as it deems desirable. Until that time it is desirable to discuss in a general way the question of changes so that they may be gotten into definite shape for action at the proper time.

Another point which should not be forgotten is that it is comparatively easy to criticize and tear to pieces, but extremely difficult to build up, so that when members of the Society criticize the

Mr. Humphrey.

specifications for cement, they should be prepared to suggest something better. The Committee is not arbitrary in its actions, nor is it disinclined to make desirable changes, but after the effort which preceded the attainment of the present Standard Specifications for Cement it is not disposed to make changes on the spur of the moment, but to thoroughly consider and study the same so that such changes which may be made will be an improvement on the specifications as they exist at the present time. The Committee may be conservative and slow, but in the end the results will speak for themselves.

REPORT OF COMMITTEE E ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

The series of paint tests planned last year and described in the last annual report of this Committee have been started. Nineteen different paints have been applied to 600 feet of the double-track deck bridge erected by the Pennsylvania Railroad over the Susquehanna River at Havre de Grace.

The record of time of cleaning, time of painting, with weather conditions, condition of paint, time of drying, condition of surface, manner of application and area of surface covered, have been tabulated and are under consideration. Analysis of the paint is being made.

The Sub-Committee on Method of Inspection after painting, has presented the following report. This method, subject to such modifications as are found necessary, will be followed.

Method of Inspection of Condition of Paints upon Havre de Grace Bridge.

(1) Inspection to be made every six months, unless for sufficient reasons the Committee desires more frequent inspections, by an official inspector. Notice of each inspection to be sent out previously to every member of the Committee with the endeavor to have the Committee represented at each inspection.

(2) As far as practicable a photograph should be taken at each inspection by a thoroughly competent photographer, preferably the inspector, care being taken to obtain negatives capable of enlargement and microscopic examination. A scale should be photographed in connection with the object.

(3) Character of gloss, to be noted by the inspector, whether high, moderate, dull or flat.

(4) Relative absorptive condition of each film when moistened with water.

(5) Relative toughness to be determined by cutting the film with a sharp knife, note being made whether elastic, tough,

brittle, or flaking, degree of adhesion being determined by the same test.

(6) Condition of surface to be noted, whether tendency to blister, alligator, scale, flake or powder (chalk), giving especial attention to the condition at angles and corners.

(7) Relative hardness to be determined by testing the films as to resistance to an edge of a cube of lead, tin, aluminum and zinc, respectively. The details are now being worked out by Mr. Heckel, and report upon the method will be made shortly.

(8) Note to be made as to the degree to which dirt has become attached to the surface.

(9) Condition of the surface as to powdering and general appearance, wear and weathering.

(10) When pitting has begun, the size, number, form, character and location of the pimple should be carefully noted, and the proportional increase since last inspection.

(11) Date to be noted on which repainting becomes necessary.

(12) These instructions are intended merely as a general guide to the inspector who will be expected to make as complete observations as possible of all matters which appear to him to be worthy of report.

The first inspection was made June 14th, and the results will be reported later.

The specification for preparation of surface and application of paint, together with instructions to the Director of Tests directly in charge of this work, was found impractical under conditions existing on this bridge.

The specifications required that all parts of structure be cleaned free from mill scale, dirt, rust, etc., to clean bright steel. This was found impractical as some of the members were badly rusted, especially in inaccessible parts, as between eye bars on bottom chord and on the latticed members. In such places it was found impossible to thoroughly clean without delaying the work to such an extent as to cause criticism from the railroad. The specifications also required that all paint be applied by the standard round pound brush. This was also found impossible on latticed members and between eye bars on bottom chord, etc.

It was found that serious delay would have resulted from a rigid adherance to the original specifications.

On account of these conditions, and rather than delay the painting of the entire bridge, the following set of instructions were issued to the Director of Tests on July 30th, 1906:

(1) The surface of all accessible metal, in so far as is practicable, is to be cleaned in a workmanlike manner with putty and broad knives, scraper and wire brushes so that all loose or easily detachable mill scale, rust and dirt are removed, as well as loose shop coat or "black oil" (by "black oil" is meant linseed). Any *non-drying oil or grease* on accessible parts is to be removed with either benzine or a torch.

(2) Where the shop coat is firm, hard, and in good condition it is not necessary to remove it. This applies also to black oil.

(3) Field and shop rivets are to be wire brushed and where necessary, this is to be followed by the knife or scraper; the hammer is not to be used.

(4) It is understood that the inside of columns and such other members difficult of access are not to enter into the test, and that the above instructions for cleaning do not apply to them. They should, however, be cleaned in accordance with the ordinary methods of the contractor. The inspector is to make note of such members and include them in his report.

(5) Painting should follow cleaning immediately, and as many different paints are to be applied at the same time as the length and position of the scaffolds and expediency will permit.

(6) No paint shall be applied when the humidity is greater than 85 per cent.

(7) Since the net cost of all work is borne by the Committee, the inspector will see that the work is done with reasonable promptness and will endeavor to keep the cost down as much as possible, consistent with reasonable thoroughness.

(8) All directions contained in the previous letter of instructions not herein modified are to remain in force.

It is felt that with the complete record of conditions of surface and application of paint given in the tabulated record sheets the value of the test has been increased.

A comparison can now be made between parts of structure prepared in varying degrees of thoroughness, and also where the paint has been applied with the standard round pound brush, with the "man-helper," a whitewash brush on long handle, and with the sheep-skin swab.

These comparisons would of course have been impossible if the original specifications had been followed. If the record of all conditions, weather, surface, application, etc., are true and trustworthy (and of this there is no ground for question) there is no doubt but that this series of paint tests has covered more ground than was originally intended and will clear up, as the test progresses, many points more or less obscure.

The plate test, it is felt, will prove of much value. These plates, 2 x 3 ft., were thoroughly cleaned to bright steel, by immersion in dilute sulphuric acid, neutralized in sodium carbonate solution, washed in running water, dried and packed in lime till painted. The paint was applied by a most skilful painter, under the most favorable conditions, at a uniform rate of spreading. Nine panels, three for each spreading rate all exposed in a very substantial frame on the down stream side of the bridge along side of the section of the bridge where the same paint was applied. A wooden walk with handrail has been erected by the Pennsylvania Railroad, on the down stream side of the bridge which will facilitate the inspection.

This test covers nineteen different paints, manufactured by sixteen different firms and includes nearly all of the leading types of paint, red lead, carbon as graphites, lampblack and carbon-black, oxide of iron with varying amounts and classes of inert materials, zinc oxide, asphaltums and special pigments. The vehicle is linseed oil in the majority of cases.

The exact composition will of course be available when analysis is completed. It will include per cent. and composition of pigment, per cent. and character of oil with approximate amount and composition of driers, presence and character of gums, as far as possible, and per cent. and identification of volatile matter with physical condition of paint, fineness of pigment, etc.

The chemical analysis has, however, required so much work that it cannot be completed in time to form a part of this report.

The total cost of the test has been somewhat more than was anticipated, and it is not possible to determine if the subscriptions from the paint manufacturers will be sufficient to cover all expenses till the balance sheet has been struck.

The Committee wishes to thank the Technological Branch of the Geological Survey and the Bureau of Standards for their co-operation and desire to aid in this investigation.

Respectfully submitted in behalf of Committee,

S. S. VOORHEES,
Chairman.

J. F. WALKER,
Secretary.

REPORT OF COMMITTEE I ON REINFORCED CONCRETE.

In the continuance of its policy of co-operating with the Joint Committee on Concrete and Reinforced Concrete it has assisted in carrying out the policy of the Joint Committee. During the year the various sub-committees into which the Joint Committee has been divided, have prepared in part, or in whole, reports on the collation of existing literature and the results of previous investigations.

These sub-committees cover the following subjects:

History.
Concrete.
  (*a*) Study of Aggregates, proportions and mixing.
  (*b*) Physical Characteristics, waterproofing, etc.
  (*c*) Strength and Elastic Properties.
Beams.
  (*a*) Simple Beams.
  (*b*) Tee Beams, Floor Slabs, etc.
Columns.
Arches.
Fire-Resisting Qualities.
Failure of Concrete Structures.

It is expected that the final reports of these sub-committees will be presented before the close of the year.

The investigations on the subject of concrete and reinforced concrete are being conducted during the present year at the Structural Materials Testing Laboratories of the U. S. Geological Survey, at St. Louis, and also in the laboratories of the Purdue University, University of Illinois, University of Wisconsin and Columbia University. The detailed program of the investigations as now being executed at St. Louis. was reported last year (Vol. VI, pp. 87–98). It is hoped that sufficient experimental work will be completed by June, 1908, to enable the Committee to prepare a report. The results of the tests made at the Structural Materials Testing Laboratories will be published in bulletin form, and it is expected that after the first of August these bulletins will appear regularly at frequent intervals.

The Committee asks that it be continued.

Respectfully submitted on behalf of the Committee,

F. E. TURNEAURE,
Chairman.

RICHARD L. HUMPHREY,
Secretary.

REPORT OF COMMITTEE J ON STANDARD SPECIFICATIONS FOR COKE.

The Committee reports progress. Through its sub-committees on Methods of Sampling and Analysis, a general letter of inquiry was directed to important consumers and manufacturers of coke, requesting information relative to their methods of sampling and analysis. A large number of replies were received, the summary of which is given in the report of the sub-committees, Appendix I. The methods of sampling as given in the replies are so varied in character, though all aiming at a fairly uniform average, that this question must be left for still further investigation.

Of the replies received the one from Mr. Wm. B. Phillips, Birmingham, Ala., is of particular interest. In part it reads as follows:

> The methods of analysis (used by myself) are practically those for coal as recommended by the Committee of the American Chemical Society. It seems to me, however, that the sulphur in coal and in coke should be given under two heads, sulphur as pyrite and sulphur as sulphate. This would require some additional research which commercial laboratories have not the time to undertake.
>
> I regard the methods now in common use for the chemical examination of coke as sufficiently accurate for ordinary purposes. There is much to be desired when it comes to the physical examination. It is here that there is the greatest need of investigation and for the adoption of standard methods. The method of Dawson, as modified by Dewey and others, gives results which are comparable only when the coal charged is practically the same in composition, fineness, degree of moisture, depth of bed and time and rate of burning.
>
> I doubt if there is any commercial product which comes into use on a large scale that exhibits so great diversities of physical structure as coke. From the same piece, weighing a few pounds, it is possible to secure cubes of marked variation in percentage of cells, in volume of cells, in apparent and true specific gravity and strength.*

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*In the second edition of his book on Iron Making in Alabama (Ala. Geol. Sur., 1898), Dr. Wm. B. Phillips published the results of many investigations of Alabama coke, using the modified Dawson method for physical tests. Up to this time, it was the most detailed investigation on the subject and the conclusions reached still hold good for Alabama coke.

Assuming that the bee-hive oven will continue to be used in coke making, modified though it maybe to meet the demands of local conditions, we have a process which seems to require a minimum of technical skill and yet which, in reality, demands technical training and experience of a high order. There are so many concurrent circumstances attending the economic use of this oven that one, at this time, may not even enumerate them. But whether the bee-hive oven or the so-called recovery oven is used, one may not expect uniformly good coke from uniformly bad materials. It does not so much matter whether we make 48- or 72-hour coke in the bee-hive oven, but it does greatly matter whether from the material charged we may reasonably expect good coke.

What we need in advancing the interests of the bee-hive oven is not so much chemical and physical investigations on the nature of the product, although these are extremely useful, as an insistence on the use of ordinary common sense between the mine and the coke-yard. If there is a variation in the nature of the coal charged there will be an accentuated variation in the nature of the coke drawn, no matter what the process may be.

But after all the value of the coke depends upon what it will do. Chemical and physical examinations may be multiplied without number, but the practical duty of coke in the blast furnace is the final court of appeals and the transfer of the case to this court involves a large expense. A difference of 250 lbs. of coke per ton of iron, on an output of 200 tons a day, may mean a difference of an hundred dollars a day. In time of great industrial activity furnace men cannot afford to make such experiments and when the times are dull they have not the money. As a rule coke is the most expensive item of the burden. It is the barometer of the cost sheet and it is strange that so little attention should be given to it. What was good or bad enough thirty years ago is good or bad enough to-day.

It is to be hoped that the investigations carried on by the Technological Division of the U. S. Geological Survey may have the important result of arousing an active concern in the possibilities of improving the nature of coke with the consequent reduction in the cost of making iron in the blast furnace and castings in the foundry.

The above letter from Dr. Phillips speaks for itself and should be read by every coke maker of the country. Work by the Committee will be continued during the coming year, and it is hoped that further data will be available for presentation at the next Annual Meeting.

Respectfully submitted on behalf of the Committee,

C. H. ZEHNDER,
Chairman.

RICHARD MOLDENKE,
Secretary.

APPENDIX I.

REPORT OF SUB-COMMITTEE ON METHODS OF SAMPLING AND ANALYSIS.

One hundred and eighty-three circular letters were sent out, and seventy-six replies received. Of these fourteen report: Report to American Chemical Society in toto; thirty-seven report: Report to American Chemical Society with modifications; twenty make no coke analysis; three make ash only; one uses Hendrich's method, and one methods outlined in Lord's Metallurgical Analysis.

As was to be expected, the greatest variation of method was in the determination of the volatile; the amount of coke used. The time of heating and the degree of heat are matters of personal selection and only in a few instances are any reasons given for such selection.

The methods for moisture show, except in a few instances, no regard for exact determination. The methods for ash are practically all in accord except for amount of sample used.

Fixed carbon is universally determined by difference between sum of moisture, volatile and ash and 100, except in one reply one-half total sulphur is estimated in volatile.

For sulphur, forty-one use Eschka's method; two use the same method with modifications; four use sodium peroxide method; one sodium peroxide, boric acid and potassium nitrate. Four use sodium carbonate and potassium nitrate mixture; and one volumetric method, sodium peroxide fusion, sodium thiosulphate and iodine titration.

The above, with analysis for phosphorus in eighteen instances, and analysis of ash, other than phosphorus, in eight instances, gives a brief outline of the nature of replies to requests for methods of chemical analysis. In goodly numbers the replies also give the methods of sampling employed, which I trust will be of assistance to the Committee.

Respectfully submitted on behalf of the Sub-Committee,

A. W. BELDEN,
Chairman.

REPORT OF COMMITTEE K ON STANDARD METHODS OF TESTING.

The Committee, recognizing the fact that the first step to be taken must be to ascertain the modes of procedure now in use at the various laboratories for testing materials, prepared a circular letter asking for a description of the methods pursued by them. The form of this letter was reported last year (Vol. VI, p. 102). It was sent to 141 laboratories in America, and to 129 in other parts of the world; or to 270 in all.

The replies came in very slowly, so that until February 1st there were not enough to distribute to the chairmen of the various sub-committees. Those received up to that time were then distributed, and others at a later date as they arrived. About forty replies have been received.

The reports of those sub-committees which have been able to make a summary of the methods pursued in these 40 laboratories, are appended hereto believing that they will be of value, while waiting to present our own conclusions and recommendations.

Respectfully submitted on behalf of the Committee,

Gaetano Lanza,
Chairman.

APPENDIX.

REPORT OF THE SUB-COMMITTEE ON TENSILE TESTS.

Twenty manufacturing firms, companies and laboratories in the United States and six in other countries responded to the request for information sent out by the Committee in regard to methods of testing in vogue. In the following list are given the names of those supplying information:

Alan Wood Iron and Steel Company.
Boston and Maine Railroad.
The American Brass Company.
American Iron and Steel Manufacturing Company.
Cambria Steel Company.
Pennsylvania Railroad.
Philadelphia and Reading Railroad.
Reading Iron Company.
Union Pacific Railroad.
Westinghouse Electric and Manufacturing Company.
Watertown Arsenal Testing Laboratory.
Chicago, Burlington and Quincy R. R. Laboratory.
Central Iron and Steel Company.
Glasgow Iron Company.
Jones and Laughlin Steel Company.
Lukens Iron and Steel Company.
Otis Steel Company, Limited.
Robert W. Hunt and Company.
Baldwin Locomotive Works.
Atchison, Topeka and Santa Fé Railroad.
The University of Australia, Sydney.
Danish Government Testing Laboratory.
Laboratory of Technical High School, Wien.
E. Suenson, Engineer, Copenhagen.
Kgl. Materialprüfungsamt, Gross Lichterfelde, West.
Chemin de fer de L'est.

The answers in the larger number of cases deal mostly with such matters as relate especially to commercial testing and in very few cases is information given in regard to work of an experimental nature.

It appears that at many testing laboratories no calibration of the testing machines is made, and at some others, methods not entirely satisfactory are used. This is largely due to the difficulty of finding a method readily applied and at the same time sufficiently accurate. Few details are given as to the mode of attachment of extensometers to specimens, but as the name of the instrument is always given, this and similiar information can be readily obtained. Very little is given as to the effect of different shaped grips on the result, the usual grip being those of a serrated, flat and V-shaped face, furnished with standard testing machines. The method for obtaining proper alignment and freedom from side bending in specimens with threaded ends, vary considerably and are of different degrees of efficiency. Practically no information is given in regard to full size tests, such tests being made at few places. A great variation occurs in the form of specimen and method of pulling cast iron, both rough and turned specimens being used.

The subjects in regard to which the smallest amount of information has been received and on which further investigation seems especially necessary are:

Mode of selection of specimens.
Methods for calibrating testing machines.
Limit of accuracy of extensometers.
The effects of different forms of grips.
Particulars in regard to full size tests.

The Boston and Maine Railroad suggests that investigations be conducted to determine some method more searching than the present one, but of a nature to be commercially practicable, whereby brittle material can be detected in cases in which the ordinary chemical and physical tests fail to establish such a condition.

JAMES CHRISTIE,
Chairman.

REPORT OF THE SUB-COMMITTEE ON TRANSVERSE TESTS.

As a result of the inquiry among the testing laboratories of this country and abroad it would seem that, outside of transverse tests of full-sized beams and the like, the transverse test is used practically for cast iron only, and then for test bars of this material. The load is always applied at the center and the speed of testing, where given, runs from ⅛ to ⅐ in. per minute in deflection.

The shape of the bars and the distance between supports gave the following record:

20 per cent. of those reporting used the Arbitration Test Bar, or 1¼ in. round, with supports at 12 in. apart.

13⅓ per cent. each had the 1 x 2 in. bar with 36 and 24 in. centers respectively.

6⅔ per cent. each had the following:

1 x 1 in. bar, 10 in., 12 in., 40 in., 54 in. and no centers given.

2 x 2 in. bar, 12 in., and 21⅓ in. centers each.

1 in. round, and no centers given.

The above list would show a great variety of methods of testing cast iron, and rather emphasize the correctness of the action of the Committee on Testing Cast Iron in adopting the now well-known "Arbitration Bar," which would give a common basis for comparison of tests in cast iron, whatever special bar the individual producer might use for his own information.

Respectfully submitted,

RICHARD MOLDENKE,
Chairman.

Answers to Questions.	C., B. & Q. Railroad.	Cambria Steel Company.	R. W. Hunt & Co.	Watertown Arsenal.
1	Yes. Car axles, Couplers, Repair knuckles.	Yes.		Limited number on softer metals.
2	Acceptance.	Deflection on axles and rails.		Compression and mechanical work.
3	M. C. B.	P. R. R. for axles. M. C. B. for rails.	M. C. B.	Vertical gravity type.
3a		1,640 lbs. for axles, 2,000 lbs. for rails.		77 lbs. to 1,000 lbs.
3b		Up to 45 feet.		1 in. to 6 feet.
3c		17,500 lbs. for axles.		30,000 lbs.
3d		Slides.		Grooved slides.
3e		Lever hook.		Frictional.
3f		Anvil supported on springs.		Rests on base 30,000 lbs. weight.
3g		Straight edge and rule.		Not complete.
3h		Concrete.		Timber grillage.
4				Cylinders 1 in. x 2 in.
5		Axle supports 3 ft. apart. Supports and tup circular.		Auxiliary block clamped to anvil.
6a		Rails, one, axles, several blows.		
6b		Different heights for different sizes.		
6c		Axles turned after third, fifth and seventh blows.		
6d		Yes.		
7		Deflection.		
8	Dimensions checked.	No.		
9	Warmed in winter.	Warmed in winter.		

A., T. & S. F. Railroad.	University of Sidney, Prof. Warren.	Danish Government Testing Laboratory.	Prof. Martens, Berlin.	Cahier des charges du Chemin de fer de l'Est.
Yes.	Yes.	Only very few.	Very many.	Yes. Cast steel, steel for locomotives, wagons, etc.
Malleability and resistance to lateral thrust.	Impact tension, flexure and compression.	Hardness of plough shares, etc.	Many purposes.	Acceptance.
Domestic, also, M. C. B. axles, couplers, draft gear	Vertical gravity type.	Vertical gravity type.	Vertical gravity type.	Vertical gravity type.
....	40 lbs. to 125 lbs.	4 to 10 lbs.	5 kg. to 1,000 kg.	50 kg.
....	Up to 15 feet.	Up to 6 feet.	....	Up to 3 meters.
....	2,800 lbs.	....	5 to 20,000 kg.	500 kg.
....	Slides.	No.	Slides.	....
....	....	Breaking electric current.	....	....
....	Rests on concrete.	....	....	....
Straight edge, rule or micrometer.	....	....	Self-registering.	....
....	Concrete.	....	Good masonry.	....
....	....	....	All kinds tension compression, flexure and shear.	Transverse.
Varies with material tested.	Transverse piece 10 in. long 3 in. diameter.	For comp. Cyl. blocks. Height 1½ times diam.	....	Supports 160 mm.
Number of blows.	Varies.	One blow.	Number of blows.	Number of blows.
Fixed weight.	Fixed.	....	Different heights.	Fixed.
Not turned except in axle test.	Transverse, not turned.	....	Varies according to work.	Turned after first blow.
Permissible but not advisable.	Time interval constant.	....	....	....
....	Extension deflection and comp.	....	Varies.	Deflection.
Only by weighing hammer.	Calibrated with standard copper plugs.	....	With copper specimens.	....
Generally warmed to about 62 degrees.	Not warmed. Min. temp. of laboratory 45° F.	....	Yes, some cases.	....

W. K. Hatt,
Chairman.

REPORT OF THE SUB-COMMITTEE ON COMPRESSIVE TESTS.

Replies to the questions have been received from ten laboratories, one in France, one in Germany, one in Austria, one in Denmark, one in Australia, and five in the United States. The answers indicate that the number of compressive tests of metals is very small compared with tensile tests. The following is a brief summary of the conclusions derived from the replies:

1. The specimens used for tests on wrought iron and steel are cubes and cylinders, the latter being more frequent. The height of the cylinders is in some cases as small as the diameter and in other cases it is 1.5, 2.0, 2.7 and 10 times the diameter.

2. Each laboratory generally recommends that form of specimen which it has been using.

3 and 4. Each laboratory uses the same form and size of specimens for cast iron as for wrought iron and steel.

5. All replies, except one, recommend that no bedding should be used for metallic specimens, and state that the essential requirements are true plane faces on both test specimens and pressure plates.

6. The replies generally imply that slow speeds should be used, especially where changes of length are to be measured.

7. Four laboratories state that the best method for determining elastic limit and modulus of elasticity is by means of a mirror apparatus, while two prefer micrometer measurements.

8. No especial distinction between tests of copper and alloys and those of iron and steel is indicated by the replies.

9. It is generally regarded that the yield point is an index of compressive strength in the case of ductile and plastic metals.

MANSFIELD MERRIMAN,
Chairman.

REPORT OF COMMITTEE M ON STANDARD SPECIFICATIONS FOR STAYBOLT IRON.

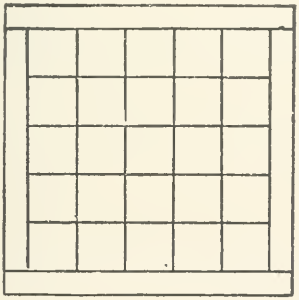
In 1905 the following specifications were submitted as initiative ones, during which time the requirements thereof have been enforced by one of the largest uses of staybolt irons. A number of large manufacturers have also adopted a method of manufacture proposed by your Committee. The Committee therefore recommend that these specifications be submitted to the Society for final consideration and action.

PROPOSED STANDARD SPECIFICATIONS FOR STAYBOLT IRON.

Specifications for Staybolt Iron of from $\frac{7}{8}$ in. to $1\frac{1}{8}$ in. in Diameter.

Process of Manufacture.—All iron staybolts must be hammered or rolled from a bloom or pile having a minium cross-sectional area of 45 square inches, and about 18 inches long.

The pile must be made up of a central core composed of bars of from $\frac{1}{2}$ in. to 1 in. square and be covered on all four sides with an envelope $\frac{5}{8}$ in. thick, as per sketch.



This pile must be rolled to a billet, allowed to cool, again heated, and then rolled into bars of the required dimensions.

Physical Tests. (*a*) Tensile Strength—not less than 48,000 lbs. per sq. in.

(*b*) Elongation—not less than 28 per cent. in 8 inches.

(*c*) Reduction of Area—not less than 45 per cent.

(*d*) Double bending test—close in both directions without flaw.

(*e*) Threading—permit of the cutting of a clear, sharp thread.

(*f*) Vibration—shall stand a minimum of 6,000 revolutions when subjected to the following vibratory tests:

A threaded specimen, fixed at one end, has the other end moved in a circular path while stressed with a tensile load of 4,000 lbs. The circle described shall have a radius of 3-32 in. at a point 8 in. from the end of the specimen.

Inspection. (*a*) The iron must be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

(*b*) It must be truly round within .01 of an inch and must not be more than .005 above, or more than .01 of an inch below specified sizes.

Selection of Samples for Test.—The bars will be sorted into lots of 100 bars each and two bars will be selected at random from each pile, failure of either of these bars to meet any of the above specifications will be cause for rejection of the lot which the tests represent.

Respectfully submitted on behalf of the Committee,

H. V. WILLE,
Chairman.

DISCUSSION.

Mr. M. H. Wickhorst.—When the spacing of staybolts is too close, there is a danger of making a net that scale catches in and cannot be washed out of. Where scale conditions are serious, that is a practical objection to getting the staybolt spacing too close. **Mr. Wickhorst**

Mr. E. D. Nelson.—The Pennsylvania Railroad has for some years used staybolts that had been reduced in the center. Although it is very difficult to get comparative results; so far as we are able to judge from the locomotives in service the indications are that bolts reduced in the center last longer than straight bolts. **Mr. Nelson.**

Mr. J. A. Kinkead.—I have consistently, I think, held two exceptions to this specification. One is the method of piling and the other the vibration test. As to the method of piling, there are staybolt manufacturers who have been making staybolt iron successfully, to the satisfaction of the consumers, for fifty or seventy-five years, whose method of piling is not in accordance with the specification. It stands to reason that if that is so, it would throw out their material. Another thing is, that one of the manufacturers has tried that method and he said that his own piling was more satisfactory. At the present time four or five vibration machines have been tried, that is of this type, but I only know of one that is said to have given check results. I have looked over some of the results and I find that the closest checking is about twenty-five per cent., which is not a practical proposition. Furthermore, we have no comparative tests between several types of machines. We have a number of machines that will test accurately for elastic limit, modulus of elasticity, reduction of area and so on. As regards the vibration, no tests have been made to find out whether these machines will compare with each other. I know some of them will not compare with themselves. It is not all in the machine. The trouble is because the pieces are tested beyond the elastic limit in the machine, and I do not believe that has any comparison with the practical service when tested within the elastic limit. **Mr. Kinkead.**

Mr. Wickhorst.—I want to corroborate what Mr. Kinkead **Mr. Wickhorst.**

Mr. Wickhorst. says. In the first place I don't think we have any business specifying the method of piling. That should be left out. And as regards the vibration test, while I don't know that I should want to go quite as far as Mr. Kinkead, yet, on the whole, in the present state of the vibration method and the special machines that are required, we are hardly prepared to put the vibration test into a general specification. At any rate it is not necessary in order to get thoroughly good staybolt iron. If we can get our elongation and particularly reduction of area, it will protect the quality of the staybolt material in a fairly good manner; possibly not as completely as desirable, but still satisfactorily enough, I think, for general purposes.

Mr. Nelson. Mr. Nelson.—I am in the unfortunate position of being a member of the Committee, but I do not like to talk out of school while Mr. Wille unfortunately is not here, although I have expressed to him the feeling that I have about the recommendation, which is evidently based on the information he had that the majority of the Committee favored his report. I want to emphasize the points made by the two last speakers; namely, in the first place, that the method of manufacture should not be included in the specification. We have found with the machine which we used as good results with other staybolt irons made by a different method of manufacture, as with iron made by this method of manufacture; and in tests which we made on the road two or three years ago, which were very complete, and included irons made by this method and others, we could not discover that there was any difference in service tests. The second point is, as already referred to, that the proposed method of testing has not been well threshed out and is not generally accepted. I think that should be done before we decide on a specification including the same.

Mr. Skinner. Mr. C. E. Skinner.—I know nothing about staybolt iron and am not on the Committee, but after hearing the remarks I would, in order to get the matter before the meeting, move that the specification be referred back to the Committee.

Mr. Marburg. Mr. Edgar Marburg.—I would suggest as an amendment that in reporting on specifications next year, if the report should not come with unanimity, that an explanatory statement concerning the differences of opinion be appended to the same.

[This amendment was accepted and the motion as amended was carried.]

REPORT OF COMMITTEE N ON STANDARD TESTS FOR LUBRICANTS.

Your Committee would respectfully offer the following report of progress:

Circular letters have been sent out from time to time and it has been agreed to compare in the first instance, the various viscosimeters used for testing oils and express the results obtained in seconds, water ratios and absolute viscosity, *i. e.*, in dynes per square centimeter. After this the flash, fire, cold, and gravity tests will be studied together with some special tests.

Arrangements are now being made to send to each member samples of various oils upon which these different tests are to be made.

Submitted on behalf of the Committee,

A. H. Gill,
Chairman.

J. M. Jeffers,
Secretary.

REPORT OF COMMITTEE O ON UNIFORM SPEED IN COMMERCIAL TESTING.

Your Committee on Uniform Speed in Commercial Testing was instructed at the last Annual Meeting to make an investigation of the effects of speed when testing iron similar to the investigation made of the effects of speed in testing steel. Your Committee herewith takes pleasure in submitting the results of its investigation. Staybolt and common iron were used in making the tests and the thanks of the Society are due the Altoona Iron Company, American Iron and Steel Company, Bethlehem Steel Company, Brown and Company (Wayne Iron Works), Lockhart Iron and Steel Company, Logan Iron and Steel Company, Hughes and Patterson, Monongahela Iron and Steel Company, and the Pittsburgh Forge and Iron Company for material furnished by the officers of these works with liberality and obliging courtesy.

Altogether 1,014 tests were made of different sized material at the speeds indicated in the tables. Of staybolt iron 250 tests were made at speeds of ½, 1, 3, 6 and 8 in. per minute. Of common iron 764 tests were made, 207 tests of round and 557 tests of common flat iron. All the tests were made at the Testing Laboratory of the Pennsylvania Railroad Company at Altoona according to and in conformity with the rules governing the testing of material for commercial purposes.

One feature of the investigation was to ascertain the possible difference in different portions of heavy bar iron. For this purpose the 5 x ⅝ and 5 x 1¼-in. iron was sawed through the middle and each side of the iron was thus tested; 515 tests of iron thus prepared were made. However, no peculiarities worth mentioning developed during this part of the investigation. No attempt was made to take the elastic limit.

Analyzing the results, more or less irregularity of strength and elongation was found in the individual tests as well as the averages. This phenomenon is due to the irregularity of structure in the metal and is found in both the staybolt and common iron except in one lot of staybolt iron which gave remarkably uniform results at all speeds. This irregularity of structure also influences the results of speed by increasing the strength at low speed.

The increase of elongation with increase of speed, in three-fourths of the tests, is a peculiarity, explainable upon the theory that the stretching of the particles of iron goes on proportionally with the speed, while the sliding of the elongated crystals, of which the iron is composed, upon each other, is disproportionate to the speed, or, in other words, the density or compactness of the metal having reached a maximum, there is little chance for the particles to slide upon each other, but, on the contrary, the softness of the metal, that is its plasticity, is sufficiently great to adjust itself and follow the accelerated motion due to the increase of force. This increase of elongation with increase of speed is also an indication of the reason why increase of speed does not increase the strength very much, if any, and what little increase does take place is due to the readjustment of the irregular portions of the metal rather than to an increase in hardness due to increasing retardation of plastic movement with increase of speed.

The reasoning that with ideal uniformity of structure, the plasticity of iron is proportionate to the speed, is confirmed by the remarkable results of the test of one of the eight lots of staybolt iron tested. The average strength of that iron at ½, 1, 3, 6 and 8 in. speeds was 52,030, 52,100, 51,570, 52,890 and 52,420 pounds respectively. The elongation with the same speeds was 31.6, 31.5, 31.7, 31.3 and 34.3 per cent. in 8 inches.

The test of this lot of iron proves that, other things being equal, speed has practically no influence in affecting the plastic adjustment of iron. The results of test of the 5 x ⅝-in. iron, by their irregularity and high strength at the three-inch speed, indicating irregularity of structure, is further proof of the correctness of the above reasoning.

The results of the eight lots of staybolt iron are instructive in this respect. The difference in strength, between lowest and highest speed, were 220, 320, 390, 410, 530, 560, 1,090 and 2,460 pounds, and the difference in elongation was 0, 1, 1.2, 1.8, 1.8, 2.2, 2.4, and 3.2 per cent., all but two being higher in elongation at the 8-inch speed, the last one being 3.2 per cent. higher.

A further proof that it is the irregularity of structure of the iron which chiefly determines the results of the tests and not the speed, we obtain by comparing the extremes of tests of different sizes of iron. Thus, with the 5 x ⅝-in. iron we have an extreme result at a one-inch speed, 11,800 pounds and 16 per cent. elongation, while at an 8-inch speed the difference between highest and lowest result is 8,600 pounds and 17 per cent. elongation. Again, with the 5 x 1¼-inch iron the extremes differed 9,200 pounds and

TABLE I.

STAYBOLT IRON.

Total Number of Tests, 250.

Speed per Minute in inches.	Diameter of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
0.50	⅞ in.	49,270	26.2
1.00		53,950	30.0
3.00		50,600	28.9
6.00		50,720	28.7
8.00		49,860	26.9

Number of Tests 60,

Speed per Minute in inches.	Diameter of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	15/16 in.	49,580	29.1
6.00		49,300	29.1
8.00		49,800	30.3

Number of Tests . . . . 18.

Speed per Minute in inches.	Diameter of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
0.50	1 in.	48,290	30.6
1.00		48,770	30.8
3.00		48,690	30.6
6.00		50,470	32.0
8.00		49,620	32.5

Number of Tests . . . . 172.

17 per cent. at a one-inch speed, and 9,800 pounds and 19 per cent. at a three-inch speed. With the $1\frac{1}{2} \times \frac{1}{2}$-inch iron we have the extremes of 4,900 pounds and 14 per cent. elongation. With the round iron we have the extremes between highest and lowest at a one-inch speed of 400 pounds and 5 per cent. elongation and at an eight-inch speed the extremes showed a difference of 300 pounds and 1 per cent. elongation. The large number of tests

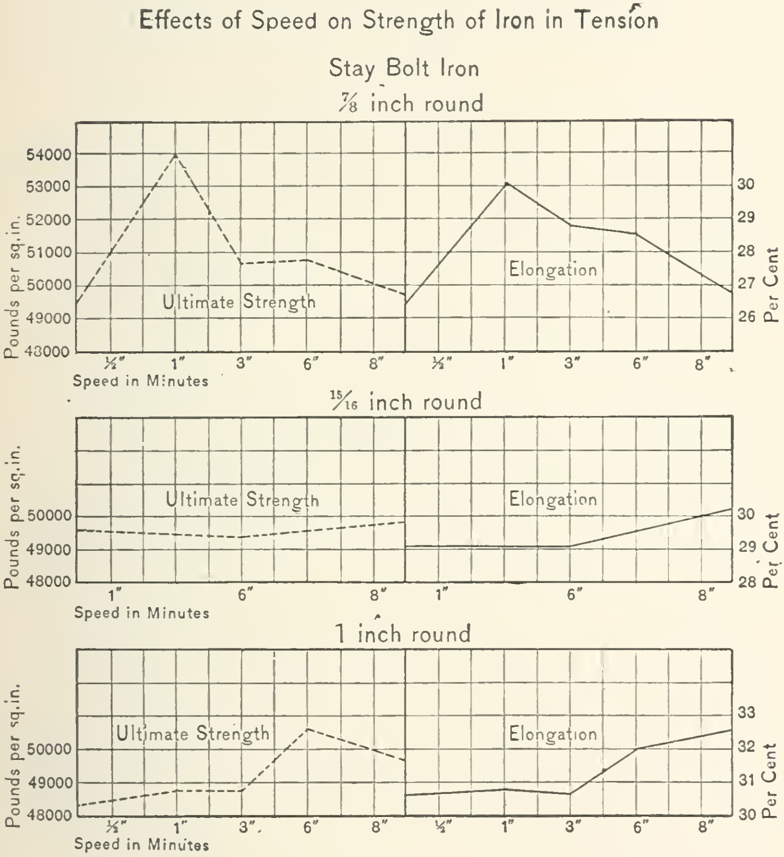


Diagram No. 1.

made bring out and emphasize these peculiarities of structural differences.

After taking these various results and factors into consideration, your Committee feels warranted in recommending that in the commercial testing of staybolt and common wrought iron any speed up to and including six inches per minute gives sufficiently safe and reliable results for commercial purposes.

TABLE II.

COMMON ROUND IRON.

Total Number of Tests, 207.

Speed per Minute in inches.	Diameter of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	½ in.	50,830	22.4
6.00		53,320	24.2
8.00		53,240	22.3

Number of Tests 30,

Speed per Minute in inches.	Diameter of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	¾ in.	51,000	22.3
3.00		51,700	24.7
6.00		52,400	25.2

Number of Tests ....15.

Speed per Minute in inches.	Diameter of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	1 in.	49,920	26.0
3.00		51,500	22.3
6.00		51,910	22.9
8.00		49,970	25.6

Number of Tests ....162.

Submitted on behalf of the Committee,

PAUL KREUZPOINTNER,
Chairman.

H. V. WILLE,
Secretary.

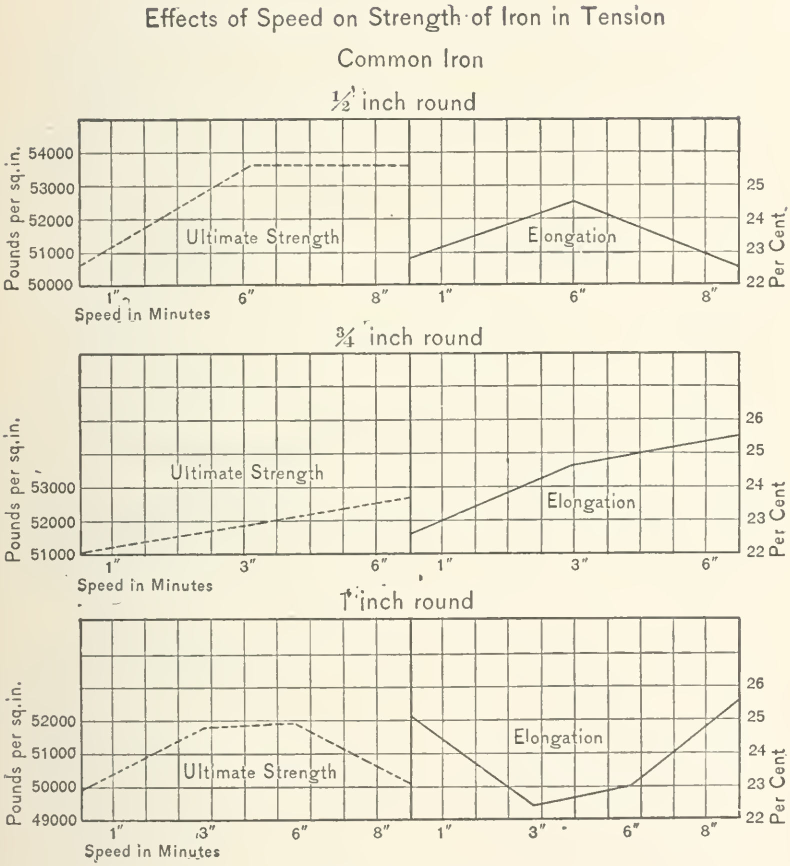

Effects of Speed on Strength of Iron in Tension
Common Iron
½ inch round
Pounds per sq. in.
54000
53000
52000
51000
50000
Ultimate Strength
Elongation
25
24
23
22
Per Cent
1″
6″
8″
1″
6″
8″
Speed in Minutes
¾ inch round
Pounds per sq. in.
53000
52000
51000
Ultimate Strength
Elongation
26
25
24
23
22
Per Cent
1″
3″
6″
1″
3″
6″
Speed in Minutes
1 inch round
Pounds per sq. in.
52000
51000
50000
49000
Ultimate Strength
Elongation
26
25
24
23
22
Per Cent
1″
3″
6″
8″
1″
3″
6″
8″
Speed in Minutes

Diagram No. 2.

TABLE III.

COMMON FLAT IRON.

Total Number of Tests, 557.

Speed per Minute in inches.	Dimensions of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	1½x½ in.	50,610	26.4
6.00		52,240	28.3
8.00		51,900	23.4

Number of Tests ....42.

Speed per Minute in inches.	Dimensions of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	5x1¼ in.	48,540	24.8
3.00		49,852	25.2

Number of Tests ....361.

Speed per Minute in inches.	Dimensions of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	5x1 in.	50,760	27.2
3.00		51,020	24.2

Number of Tests 16

Speed per Minute in inches.	Dimensions of Iron.	Tensile Strength. Pounds per sq. in.	Elongation in 8 in. Per cent.
1.00	5x⅝ in.	51,750	24.1
3.00		55,600	29.3
6.00		52,030	23.4
8.00		50,930	21.3

Number of Tests..................138

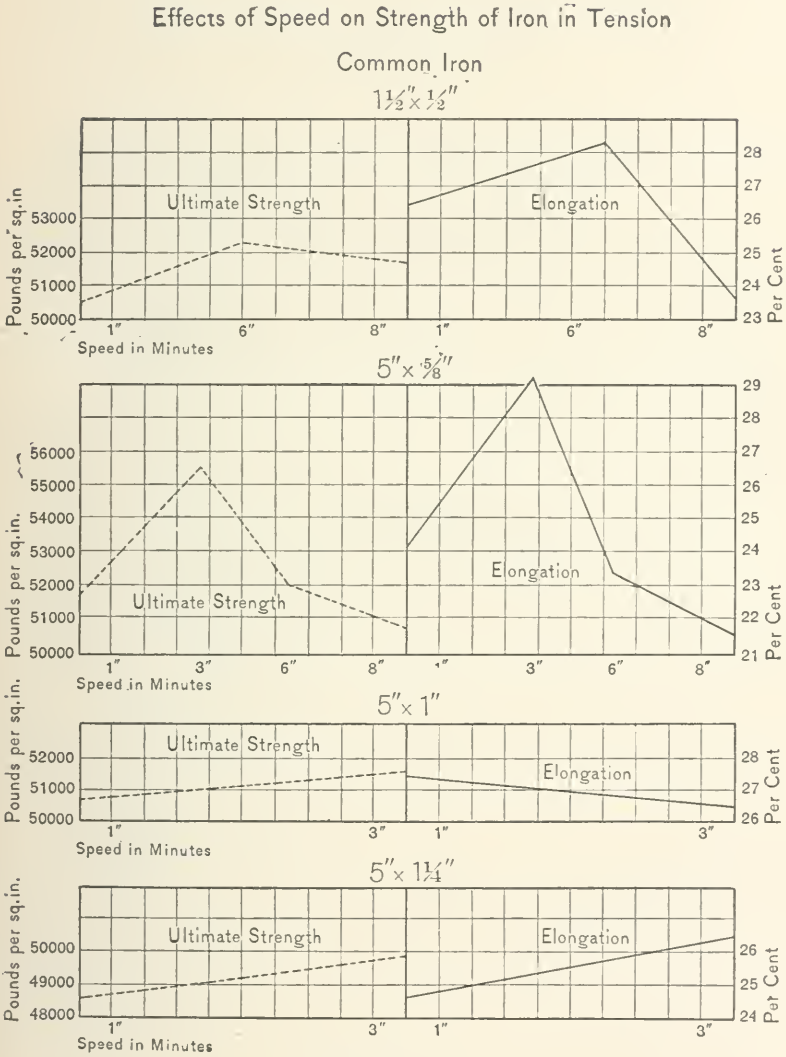

Effects of Speed on Strength of Iron in Tension
Common Iron
1½″ x ½″
Ultimate Strength
Elongation
Pounds per sq. in
53000
52000
51000
50000
28
27
26
25
24
23
Per Cent
1″
6″
8″
1″
6″
8″
Speed in Minutes
5″ x ⅝″
56000
55000
54000
53000
52000
51000
50000
Pounds per sq. in.
Ultimate Strength
Elongation
29
28
27
26
25
24
23
22
21
Per Cent
1″
3″
6″
8″
1″
3″
6″
8″
Speed in Minutes
5″ x 1″
Pounds per sq. in.
52000
51000
50000
Ultimate Strength
Elongation
28
27
26
Per Cent
1″
3″
1″
3″
Speed in Minutes
5″ x 1¼″
Pounds per sq. in.
50000
49000
48000
Ultimate Strength
Elongation
26
25
24
Per Cent
1″
3″
1″
3″
Speed in Minutes

Diagram No. 3.

REPORT OF COMMITTEE P ON FIREPROOFING MATERIALS.

Your Committee collated and presented at the last annual meeting of the Society all the information available at that time regarding fire tests on floor constructions both in this country and in England. The detailed information regarding these tests was presented in the tables accompanying that report (Vol. VI, p. 128). It will be noted that in several instances no information is given except the time and place of the test. In these cases no recorded information was obtainable. These tables represent the sixty-three fire tests made in this country, and seventeen in England.

The tests in America were all made under the supervision of the building authorities in New York City, though some of them were made in conjunction with the building authorities of Philadelphia. The English tests were all made under the immediate direction of the British Fire Prevention Committee.

From a careful study of these data, the Committee would suggest the following outline of a standard test for fireproof floor constructions.*

Respectfully submitted on behalf of the Committee,

Ira H. Woolson,
Chairman.

R. P. Miller,
Secretary.

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* This standard test was adopted as recommended and appears on page 179.

DISCUSSION.

Mr. Ira H. Woolson.—This report is in print and has been distributed among you. It is in the form presented at the meeting last year together with the tables of data which the Committee was able to collect and upon which this proposed method of test was based. It was accompanied with the request that comments and criticisms should be addressed to the Committee so that during the ensuing year we might be able to modify it and present it in a final form. I regret to say that we have not received a single comment. However, for fear you may not have given the subject any special consideration; it is open for discussion at the present time. Mr. Woolson

The specification is simply one of others that will be made, this one covering tests of fire-resisting floor construction.

After the Society has made such modifications as seem advisable, I suppose the proper procedure would be to refer the report to letter ballot.

Mr. R. L. Humphrey.—I should like to ask the Chairman whether it is necessary to specify a wood fire, and whether gas is not as suitable; in other words, would it not be sufficient for the specification to require a continuous heat, averaging not less than 1700° F.? Mr. Humphrey.

Mr. Woolson.—Because the Committee are very firmly of the opinion that wood is the best material for a test of this character. I have seen tests made using gas as a fuel; and my experience is not favorable to gas. The gas is supplied in jets through the floor of the building; and they form a series of fire columns throughout the structure, with strong air drafts between the columns of flame. In course of time the heat becomes more or less distributed, to be sure; but it is nevertheless concentrated at certain points and you do not have the uniform radiation over the whole surface that you get from a burning pile of wood. Furthermore, with wood fuel you get the strong flame action of a conflagration and exactly the same chemical conditions, as well as conditions of draft as nearly Mr. Woolson.

Mr. Woolson. as these can be imitated. My opinion, based upon the experience of conducting some fifty or more of these tests, is that wood is by all odds the best fuel. It is more difficult to make a test with wood; because you have the labor of handling it. However, a test of this character can be made anywhere; one is not compelled to go to some particular place to make a test. It is an expensive affair to install a test plant for use of gas, regardless of whether the gas is manufactured fòr the purpose or taken from a public supply. These specifications make the test perfectly adaptable to any place

Mr. Humphrey. MR. HUMPHREY.—It seems to me that with a uniform temperature of 1700° F. on the bottom of a floor slab, it would be immaterial whether that heat had been obtained by the use of wood or any other fuel. There are many places where it would not be possible to secure cord-wood, but it would be comparatively easy to secure gas.

Mr. Brown. MR. JOHN G. BROWN.—I should like to ask Mr. Woolson why four hours are specified as the time limit of the test. I have had one or two tests made; and on inquiring of different fire underwriters I find that fire confined to one room lasts usually a half to three-quarters of an hour. A four-hour limit seems therefore a very severe test.

Mr. Woolson. MR. WOOLSON.—The statement made by Mr. Brown regarding the duration of the ordinary fire in a room is, I think, approximately correct. It would be hard to conceive of a room in an ordinary building that would have inflammable material enough in it to maintain a temperature of 1700° F. for more than an hour, or perhaps an hour and a half at the outside; but the period of four hours which we have adopted is the period which was adopted by the Bureau of Buildings of New York City several years ago, and has been under pretty sharp discussion time and again between that Bureau and others interested. We arrived at the conclusion, however, that the test is not too severe for this reason: the whole object of these tests is to differentiate poor material from good and we know that among the various classes of fire-proof construction there are many which can pass this test. That being the case, the test is not more severe than can be met by a good material. It is severe enough to throw out, as it has in the past, a considerable number of inferior constructions, inferior either in design or material. In an investigation of this kind, where the whole object of the test is to secure protection of property and perhaps of life, the supposition is that nothing is too good. If nothing is too good, and these specifications are not too severe to be met; then the specifications are not too severe. **Mr. Woolson.**

We must also face this situation: any structure put up for test is bound to be better constructed than it would be in ordinary practice. That goes without saying, particularly where workmanship and selection of materials are concerned; consequently we should make the tests rigid enough to eliminate the influence of superior workmanship and material. On that basis it would also appear that the test is not too severe.

Mr. Miller. MR. R. P. MILLER.—I want to add just a word to what Professor Woolson has said. While I concede that under ordinary conditions, and generally speaking, a fire of 1700° F. does not last more than an hour, or an hour and a half, yet I have known such fires to last four hours. We are looking for a floor that will stand the severest conditions; not the floor that will stand merely the ordinary conditions. In a fire-proof building we must construct the building so that it can be used for any purpose. In a clothing warehouse, for instance, the material does not burn with a large flame but smoulders for a long time with intense heat as has been the experience in such cases in New York. The original test in New York, under the auspices of the Department of Buildings, was a test of five hours; and of the sixty odd tests made under the auspices of the New York building authorities more than a dozen were made under the five-hour limit. The Committee discussed that matter of time very carefully; and we considered that the four-hour limit was enough. It is true that most people regard it as too severe and that seems to be the sentiment here, but, as Mr. Woolson has suggested, we have found a large number of materials and constructions that will stand that test, and why should we not have the best?

Mr. Humphrey. MR. HUMPHREY.—In connection with the fire tests that are being made in Chicago at the Underwriters' Laboratories, the representatives of the various societies interested in this work, namely, the National Fire Protection Association, the National Board of Fire Underwriters, the Joint Committee on Concrete and Reinforced Concrete and the National Association of Cement

Mr. Humphrey. Users, met with a view of determining the duration of the heat that should be applied in the testing of concrete and other materials commonly used in the fire-proofing of building materials.

After considering the matter, it was finally decided that the duration of this test should be two hours, the temperature ranging between 1700° and 1800° F., and that immediately at the end of that time a jet of water under 50 pounds pressure and at a distance of 20 feet should be played on the surface of the material under test.

After testing the various building materials, it has been found that the test was sufficiently severe, since every material failed, none passing the test; of course the test offers a reliable comparison of the quality of the various materials since the degree of failure is comparable. In the case of buildings it is necessary to fire-proof the structural parts, and the thickness of this fire-proofing will depend upon the probable duration of the fire to which it may be subjected. This is a matter of judgment, and it is manifest that an office building will not be subjected to a fire of the same duration or intensity as a warehouse. There are a number of instances in the San Francisco fire where quantities of inflammable materials burned for a long time at an extremely high temperature. The question of fire-proofing is thus one of degree. Since two hours proved sufficient in the Chicago test, it seems unnecessarily severe to carry on the test for four hours. The whole fire-proofing problem resolves itself into a determination of the resisting qualities of the various building materials, that is, the rate of conductivity or penetration of the heat. If this can be determined in a two-hour test it seems undesirable to prolong it to four.

Mr. Douty. MR. D. E. DOUTY.—I rise, not to discuss the specifications, but simply for information.

I notice, in the first sentence of the preliminary statement, that the information has been gained from tests carried on in this country and in England. I should like to ask the Chairman of the Committee if any consideration has been given to the tests which have been carried on at the Materialprufüngsamt in Charlottenburg. The building section there has been engaged in this kind of work for a long time, testing the fire-proofing of doors, windows, walls and floors, and everything of that sort; and some very valuable data is collected in the "Mittheilungen" of that institution. I am not sufficiently familiar with the data to say whether it would add anything to the subject or not; but, while I simply make the suggestion, it seems to me well to have the Committee look this work over and determine if it is anything that would be of value to us in this country. Mr. Douty.

MR. WOOLSON.—At the time the Committee started its work we sent out a circular letter asking for information. It was sent to every possible source we could think of that would have information on that subject, and included the laboratories at Charlottenburg, and my impression is that we did not receive a communication from that laboratory. While in Europe three years ago I visited those laboratories and investigated the work that was being done there. I also had a talk with some of the officials who were doing work both there and at the meeting of the International Fire Prevention Congress in London. I found nothing up to that time that was really comparable with our work here. There was a lack of uniformity in methods of test, and duration of same. There was no systematic methods of fire tests at Charlottenburg so far as I was able to learn, and there were no reports in printed form or otherwise that we could get. I did not think at that time there was anything there that really compared with the excellent work of the British Fire Prevention Association, or the work that was being done here. I did not know anything about the published reports of which Mr. Douty speaks. Mr. Woolson

MR. DOUTY.—I know the publications do contain a number of articles on fire tests. They built miniature houses and fired them in all sorts of ways, and also made some tests upon conductivity; I suggest that as perhaps a valuable source of information. Mr. Douty.

MR. WOOLSON.—In England they were making tests of two hours; then they changed to three hours; and they are now coming to four hours. One or two other specifications which have been adopted here and which they objected to three years ago, they are now adopting—at least, it so appears from recent reports. Mr. Woolson.

THE CHAIRMAN (Mr. Robert W. Lesley).—The Chair would like to call the attention of the Committee and of the meeting to a state of facts that possibly we might well consider at this time. The Chairman.

This Society is a society for testing materials. Incidental to the work of this Society it is a member of the Joint Committee on Concrete and Reinforced Concrete. That Committee has been

The Chairman. doing work for several years in the matter of standard specifications, or standard methods for concrete construction. Incidental to that, this Committee, of which Professor Woolson is Chairman, has been contributing most valuable work.

The point to which I desire to call attention is that this report is entitled a "Report of Committee P: On Fire-proofing Material." Now it seems to me that we should bear in mind, definitely and clearly, that this Committee, if its title is a Committee on Fire-proofing Material, must deal not only with concrete but with all fire-proofing materials; and therefore, it strikes me, that if there be any other form of fire-proofing, hollow tiles, mackite, or any other material, that this Committee should charge itself with the examination thereof. We should have to restrict its title if it is confining its attention to concrete alone. In other words, the American Society for Testing Materials with its committees stands for fair play for all materials having a common use and a common purpose, and we do not want the specifications that go to the public to be questioned as being influenced by cement men, by concrete men, or by men in any other form of industry or trade. This is a broad scientific body, and not a trade organization. I hope to hear from the Chairman of this Committee as to the general purposes of the Committee in dealing with hollow tile and all other forms of fire-proofing construction; and I hope that this specification applies, not to one form, but to all forms.

Mr. Woolson. MR. WOOLSON.—I agree entirely with the remarks of the Chairman. I think that the specifications should be written to cover any and all materials with absolutely no distinction. It was the purpose of the Committee, in writing this specification, that it should cover all kinds of construction. I might add that this same specification, or practically the same, has been applied to tile construction. I have personally conducted several tests upon tile construction built in New York and Pittsburg or vicinity; so I know that tile will meet the specification.

Mr. Miller. MR. R. P. MILLER.—We must remember this: that in drawing our conclusions from tests that have been made, we have had to consider such as were made; and the Committee had no means of making tests of its own on different materials. As you will see in reading this specification, it is a specification for the form of test to be made, not a specification for any particular type or material.

Now as a matter of fact there have been other materials besides concrete and hollow tile. When I speak of concrete, I include cinder concrete and stone concrete of various compositions. A material that comes particularly to my mind now is a plaster composition which was tested under practically this specification; that is, this specification is practically the specification that is given in the present New York Building Law. **Mr. Miller.**

In considering this specification, the Committee kept fully in mind, as stated here, the 17 tests that were made in England under the auspices of the British Fire Prevention Committee, which included, I believe, even tests on wood beams covered with plaster of different kinds.

THE CHAIRMAN.—The Chair desires to say that if the hollow tile interests or any other interests having to do with fire-proofing feel that they should have representation on our Committee on Fire-proofing, or that they should be represented on the floor at our meetings, this Society stands for the fullest and widest discussion of the subject. Everybody should have his day in court and every interest should be given fair play and no favor. I think that is the spirit in which we must meet this question. **The Chairman.**

MR. MERRIMAN.—The specification requires that the deflection shall not exceed $\frac{1}{8}$ of an inch for each foot of span. I would like to ask how this rule has been established, and whether it is true that the deflection will vary directly as the span. If the span is 8 feet, the deflection must not exceed 1 inch; if the span is 16 feet it must not exceed 2 inches. My understanding is that the deflection must increase in very much faster ratio than the span; in the case of a beam, under ordinary working loads, the deflection increases as the cube of the span. This does not strictly apply beyond the elastic limit; but I would expect that the deflection of a 16-foot span would be four or five times that of an 8-foot span. **Mr. Merriman.**

MR. MILLER.—In the matter of the deflection, the specification is not one for the strength of the construction. The strength of the construction must be considered independently of that. This test is to determine the fire-proof character of any particular construction. As far as this deflection being proportionate to the span is concerned, the only reason for putting in any requirement as to the deflection was that we found that the deflection in these constructions is due to the heating of the material, rather than the **Mr. Miller.**

Mr. Miller. load placed upon it; because the load remains uniform or constant throughout the test. The deflection that does occur is due to the expansion of the material, or the weakening of the material due to high temperatures; and the idea is to guard against excessive permanent deflection. Some of these constructions deflect considerably during the test; but when the water is applied and the construction cools, it comes back or very nearly, in many instances, to its original position.

Mr. Thompson. Mr. Sanford E. Thompson.—Criticism has been made of the length of the test subject to fire. In a congested city like New York it is certainly wise to have a uniform test like that. But I should like to ask the Committee if, in view of the fact that these specifications are for general use, whether it would not be advisable to designate two classes, the tests for second-class materials being less severe. That would meet the great differences in the contents of buildings and their location.

Mr. Woolson. Mr. Woolson.—I think that might be feasible. If a manufacturer were content to take a second-class rating, his material might answer for certain classes of work. There are manufacturers who would be glad to take a second-class rating; in fact glad to get a rating at all, since they know they can't meet this one.

[On motion it was decided to submit the proposed Standard Test for Fire-proof Floor Construction to letter-ballot.]

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD TEST FOR FIRE-PROOF FLOOR CONSTRUCTION.

ADOPTED SEPTEMBER 1, 1907.

The test structure may be located at any place convenient to the applicant, where all the necessary facilities for properly conducting the test are provided.

The test structure may be constructed of walls of any material not less than twelve inches thick, properly buttressed on all sides.

The floor construction to be tested shall form the roof of the test structure.

At a height of not less than 2 ft. 6 in., nor more than 3 ft. above the ground level, a metal grate, properly supported, shall be provided, covering the whole inside area of the building.

In the walls below this grate level, draught openings shall be provided, as many as possible, furnishing openings with an aggregate area of not less than one square foot for every ten square feet of grate surface. Means for temporarily closing these openings should be provided.

In the wall, immediately above the grate level, a firing door, 3 ft. 6 in. by 5 ft. high, must be provided in the side of the building at right angles to the floor beams. A second door must be added when the span of the floor slab under test exceeds ten feet.

Flues should be supplied at each of the corners, and oftener in case of a test structure exceeding 250 square feet of grate surface, with sufficient opening to insure a proper draught, securely supported and disposed at the sides of the structure in such manner as not to rest on the floor under test. In no case should a flue area be less than 180 square inches.

The horizontal dimensions of the test structure will depend upon the number and the span of the systems under consideration. The clear span of the floor beams is to be 14 ft. The distance between floor beams, or span of slab, may be varied according to the design of the system to be tested, and should be as near as possible to usual practice. The underside of the construction under test must be not less than 9 ft. 6 in. nor more than 10 ft. above the grate level.

The construction to be tested should be designed for a working load of one hundred and fifty pounds per square foot, and no more. This load to be uniformly distributed without arching effect, and to be carried on the floor during the fire test.

The floor may be tested as soon after construction as desired, but within forty days. Artificial drying will be allowed if desired.

The floor is to be subjected to the continuous heat of a wood fire, averaging not less than 1700° F. for four hours.

The heat obtained shall be measured by means of standard pyrometers, under the direction of an experienced person. The type of pyrometer is immaterial so long as its accuracy is secured by proper standardization. The heat should be measured at not less than two points when the main floor span is not more than ten feet, and one additional point when it exceeds ten feet. Temperature readings at each point are to be taken every three minutes. The heat determination shall be made at points directly beneath the floor so as to secure a fair average.

At the end of the heat test a stream of water shall be directed against the underside of the floor, discharged through a one and one-eighth inch nozzle, under sixty pounds nozzle pressure, for ten minutes.

After the floor has sufficiently cooled the load on the same shall be increased to six hundred pounds per square foot, uniformly distributed.

The test shall not be regarded as successful unless the following conditions are met: No fire or smoke shall pass through the floor during the fire test; the floor must safely sustain the loads prescribed; the permanent deflection must not exceed one-eighth inch for each foot of span in either slab or beam.

REPORT OF COMMITTEE Q ON STANDARD SPECIFICATIONS FOR THE GRADING OF STRUCTURAL TIMBER.

The organization of the Committee is as follows:

Hermann von Schrenk, *Chairman.*
W. K. Hatt, *Secretary.*

Sub-Committee on Bridge and Trestle Timbers:

W. K. Hatt, Purdue University, Lafayette, Ind.
B. E. Fernow, Ithaca, N. Y.
M. B. Nelson, Long-Bell Lumber Company, Kansas City, Mo.
H. W. Lohmann, 302 Lincoln Trust Building, St. Louis, Mo
A. F. Robinson, A., T. & S. F. Ry., Chicago, Ills.
D. W. Lum, Southern Ry., Washington, D. C.

Sub-Committee on Car Sills and Car Framing:

R. S. Kellogg, Forest Service, Washington, D. C.
Chas. E. Davis, 25 Broad Street, New York, N. Y.
M. B. Nelson, Long-Bell Lumber Company, Kansas City, Mo.

Sub-Committee on Framing for Buildings:

E. J. Russell, Chemical Building, St. Louis, Mo.
J. L. Mauran, Chemical Building, St. Louis, Mo.
M. R. Sanguinet, Home Building, Fort Worth, Texas.
A. O. Elzner, 136 Ingalls Building, Cincinnati, Ohio.
M. B. Nelson, Long-Bell Lumber Co., Kansas City, Mo.
W. S. Eames, Lincoln Trust Building, St. Louis, Mo.

Sub-Committee on Ship Timbers:

Alex. J. Maclean, Fordham Heights, New York City.

Sub-Committee on Cross Arms for Poles:

A. N. Mansfield, 125 Milk Street, Boston, Mass.
C. R. Bangs, 15 Dey Street, New York, N. Y.
W. M. Carpenter, Heyworth Building, Chicago, Ills.

During the year meetings were held on February 2 and May 11, at St. Louis, Mo.

A meeting of the Sub-Committee on Bridge and Trestle Timbers was held jointly with the Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association at Chicago, March 19, at which standard specifications for bridge and trestle timbers were adopted to be reported by the two Committees to their respective organizations.

I. DEFINITION OF STRUCTURAL TIMBER.

No change has been made in the definition as recommended in the report of the Committee for 1906.

II. STANDARD DEFECTS.

The Committee has made revision as follows:

Insert the footnote found on page 130, Proceedings, Vol. VI, 1906, in the body of the report, immediately following the introductory paragraph.

In the definition of spike knot, change the word "diameter" to "width."

Definition of "Ring Shake" and "Through Shake" added.

The definitions of standard defects, modified as above, are given on page 187.

III. STANDARD NAMES FOR STRUCTURAL TIMBERS.

After a large amount of correspondence with lumber dealers, botanists, and other interested parties, the standard names as recommended in the report of the Committee for last year were modified as follows:

Referring to the Proceedings, Vol. VI, 1906.

Page 132, line 22, the word "Cuban" inserted after the word "if."

Page 132, line 29, the words "or pine" inserted after the words "Puget Sound fir."

Page 133, No. 10, the word "white" omitted from the term "western white pine," making the term as adopted "western pine." Also the words "western white pine" inserted, line 10, after the words "white pine."

The standard names and definitions of defects as reported by Committee Q last year were recommended to the American Railway Engineering and Maintenance of Way Association, January, 1907, by the Committee on Wooden Bridges and Trestles, with the exception that southern yellow pine is made to include three classes: (*a*) longleaf pine, (*b*) shortleaf pine, (*c*) loblolly pine, and the term western white pine is used.

This Committee also includes the standard names for oak.

The trade names as now recommended are given on page 189.

IV. STANDARD SPECIFICATIONS FOR BRIDGE AND TRESTLE TIMBERS.

These specifications are given on page 190.

V. PROPOSED SPECIFICATIONS FOR CAR SILLS AND CAR FRAMING FOR FREIGHT CARS.

The following specifications have been considered by the Committee, and are submitted as a preliminary report, it being the intention of the Committee to give these further consideration during the coming year:

GENERAL RULES.

All timber shall be sound, sawed standard size, square edged, unless otherwise specified, free from unsound or loose knots, knot holes, and ring shakes.

Standard Size of Sawed Timbers.—Rough timbers when sawed to standard size, shall mean that they shall not be over $\frac{1}{4}$ in. scant from actual size specified. For instance, a 12 in. x 12 in. shall measure not less than $11\frac{3}{4}$in. x $11\frac{3}{4}$ in.

Standard Dressing of Sawed Timbers.—Standard dressing means that not more than $\frac{1}{4}$ in. shall be allowed for dressing each surface. For instance, a 12 in. x 12 in. shall after dressing four sides, not measure less than $11\frac{1}{2}$ in. x $11\frac{1}{2}$ in.

SILLS.

No. 1. *Longleaf Pine or Douglas Fir.*—Shall be square edged and show not less than 85 per cent. heart on wide faces, measured anywhere in the length of the piece; sound, tight knots less than 2 in. in diameter and standard pitch pockets permitted when not clustered; grain must be close and straight.

No. 2. *Longleaf Pine, Shortleaf Pine, Norway Pine, Western Pine, Douglas Fir, Western Hemlock.*—Same specifications as for No. 1, except that sound, tight knots less than 2½ in. in diameter, if well scattered, will be permitted in longleaf pine and Douglas fir; wane not to exceed 10 per cent. of the width of adjacent faces will be permitted on opposite corners not to exceed one-half the length of the piece.

END SILLS, END PLATES, POSTS, BRACES, AND CARLINES.

No. 1. *White or Red Oaks.*—Shall show not less than 85 per cent. heart on each face, measured anywhere in the length of the piece; well-scattered, standard knots permitted.

No. 2. *Longleaf Pine or Douglas Fir.*—Shall show not less than 85 per cent. heart on each face, measured anywhere in the length of the piece; must be close, straight-grained, and free from all defects, except well-scattered, sound, tight knots, not over 1 in. in diameter.

SIDE PLATES.

No. 1. *Longleaf Pine, Douglas Fir.*—Shall show not less than 85 per cent. heart on wide faces, must be close, straight-grained; well-scattered, standard knots and standard pitch pockets permitted.

No. 2. *Longleaf Pine, Douglas Fir, Western Pine, Western Hemlock, Shortleaf Pine.*—Same as for No. 1, except that a few well-scattered, large knots will be permitted in longleaf pine and Douglas fir.

VI. FRAMING FOR BUILDINGS.

The following specifications for framing for buildings are submitted as a preliminary report, it being the intention of the Committee to give further consideration to these during the coming year:

PROPOSED SPECIFICATIONS FOR TIMBER REQUIRED IN THE CONSTRUCTION OF BUILDINGS.

General Requirements.

All timber shall be cut from sound timber and sawed standard size, close grained, free from ring shakes, decay and unsound knots, or knots and other defects that will materially impair its strength and durability.

Standard Size of Sawed Timber.—Rough timbers when sawed to standard size, shall mean that they shall not be over ¼ in. scant from actual size specified. For instance, a 12 in. x 12 in. shall measure not less than 11¾ in. x 11¾ in.

Standard Dressing of Sawed Timbers.—Standard dressing means that not more than ¼ in. shall be allowed for dressing each surface. For instance, a 12 in. x 12 in. shall after dressing four sides, not measure less than 11½ in. x 11½ in.

Posts: Longleaf Yellow Pine.

Will admit 1 in. wane on corners as measured on faces of timber. Must be free from knots 3 in. in diameter or over, and knots must not be in groups.

Beams and Girders: Longleaf Yellow Pine.

Will admit 1 in. wane on one corner as measured on faces of timber. Sound knots less than 3 in. in diameter will be permitted on the vertical faces at points not less than one quarter the depth from the edge of the piece; sound, tight knots not exceeding 1½ inches at other points, provided they are not in clusters.

Joists: Longleaf Yellow Pine, Shortleaf Yellow Pine.

All joists over 2 in. in thickness to comply with the requirements for beams and girders.

Joists 2 in. in Thickness, will admit sound knots, none of which in 2 x 4's should be larger than 2 in. in diameter on one or both sides of the piece, and on wider stock which do not occupy more than one-third of the cross-section at any point throughout its length if located at the edge of the piece; or more than one-half of the cross-section if located away from the edge; pith knots, or smaller or more defective knots which do not weaken the piece more than the knot aforesaid; will admit of seasoning checks, firm red heart, heart shakes that do not go through, wane ¾ deep on edge, ¼ the width and ⅓ the length of the piece, pitch, sap stains, pitch pockets, splits in ends not exceeding in length the width of the piece, a limited number of small worm holes well scattered, and such other defects as do not prevent its use as substantial structural material.

VII. During the year progress reports have been submitted by the Sub-Committee on Cross Arms for Poles and the Sub-Committee on Ship Timbers.

CONCLUSIONS.

1. The Committee recommends that the following specifications be submitted to letter ballot:

(*a*) Definition of defects.
(*b*) Standard names for structural timbers.
(*c*) Standard specifications for bridge and trestle timbers.

2. The Committee submits the following as preliminary reports:

(*a*) Specifications for car sills and car framing.
(*b*) Specifications for framing for buildings.

Respectfully submitted on behalf of the Committee,

HERMANN VON SCHRENK,
Chairman.

W. K. HATT,
Secretary.

AMERICAN SOCIETY FOR TESTING MATERIALS
PHILADELPHIA, PA., U. S. A.
AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR STRUCTURAL TIMBER.

ADOPTED SEPTEMBER 1, 1907.

I. DEFINITION OF STRUCTURAL TIMBER.

By the term "Structural Timber" the Committee understands all such products of wood in which the strength of the timber is the controlling element in their selection and use. The following is a list of products which are recommended for consideration as structural timbers:

Trestle Timbers.—Stringers, caps, posts, mud sills, bracing, bridge ties, guard rails.

Car Timbers.—Car framing, including upper framing; car sills.

Framing for Buildings.—Posts, mud sills, girders, framing, joists.

Ship Timbers.—Ship timbers, ship decking.

Cross Arms for Poles.

II. STANDARD DEFECTS.

Measurements which refer to the diameter of knots or holes should be considered as referring to the mean or average diameter.

1. *Sound Knot.*—A sound knot is one which is solid across its face and which is as hard as the wood surrounding it; it may be either red or black, and is so fixed by growth or position that it will retain its place in the piece.

2. *Loose Knot.*—A loose knot is one not firmly held in place by growth or position.

3. *Pith Knot.*—A pith knot is a sound knot with a pith hole not more than $\frac{1}{4}$ inch in diameter in the center.

4. *Encased Knot.*—An encased knot is one which is surrounded wholly or in part by bark or pitch. Where the encasement is less than $\frac{1}{8}$ of an inch in width on both sides, not exceeding one-half the circumference of the knot, it shall be considered a sound knot.

5. *Rotten Knot.*—A rotten knot is one not as hard as the wood it is in.

6. *Pin Knot.*—A pin knot is a sound knot not over $\frac{1}{2}$ inch in diameter.

7. *Standard Knot.*—A standard knot is a sound knot not over $1\frac{1}{2}$ inches in diameter.

8. *Large Knot.*—A large knot is a sound knot, more than $1\frac{1}{2}$ inches in diameter.

9. *Round Knot.*—A round knot is one which is oval or circular in form.

10. *Spike Knot.*—A spike knot is one sawn in a lengthwise direction; the mean or average width shall be considered in measuring these knots.

11. *Pitch Pockets.*—Pitch pockets are openings between the grain of the wood containing more or less pitch or bark. These shall be classified as *small, standard* and *large* pitch pockets.

(*a*) *Small Pitch Pocket.* A small pitch pocket is one not over $\frac{1}{8}$ of an inch wide.

(*b*) *Standard Pitch Pocket.* A standard pitch pocket is one not over $\frac{3}{8}$ of an inch wide, or 3 inches in length.

(*c*) *Large Pitch Pocket.* A large pitch pocket is one over $\frac{3}{8}$ of an inch wide, or over 3 inches in length.

12. *Pitch Streak.*—A pitch streak is a well-defined accumulation of pitch at one point in the piece. When not sufficient to develop a well-defined streak, or where the fiber between grains,

that is, the coarse-grained fiber, usually termed "Spring wood," is not saturated with pitch, it shall not be considered a defect.

13. *Wane.*—Wane is bark, or the lack of wood from any cause, on edges of timbers.

14. *Shakes.*—Shakes are splits or checks in timbers which usually cause a separation of the wood between annual rings.

15. *Rot, Dote* and *Red Heart.*—Any form of decay which may be evident either as a dark red discoloration not found in the sound wood, or the presence of white or red rotten spots, shall be considered as a defect.

16. *Ring Shake.*—An opening between the annual rings.

17. *Through Shake.*—A shake which extends between two faces of a timber.

III. STANDARD NAMES FOR STRUCTURAL TIMBERS.

1. *Southern Yellow Pine.*—Under this heading two classes of timber are used, (*a*) Longleaf Pine, (*b*) Shortleaf Pine.

It is understood that these two terms are descriptive of quality, rather than of botanical species. Thus, shortleaf pine would cover such species as are now known as North Carolina pine, loblolly pine, and shortleaf pine. "Longleaf Pine" is descriptive of quality, and if Cuban, shortleaf, or loblolly pine is grown under such conditions that it produces a large percentage of hard summer wood, so as to be equivalent to the wood produced by the true longleaf, it would be covered by the term "Longleaf Pine."

2. *Douglas Fir.*—The term "Douglas Fir" to cover the timber known likewise as yellow fir, red fir, western fir, Washington fir, Oregon or Puget Sound fir or pine, norwest and west coast fir.

3. *Norway Pine,* to cover what is known also as "Red Pine."

4. *Hemlock,* to cover Southern or Eastern hemlock; that is, hemlock from all States east of and including Minnesota.

5. *Western Hemlock,* to cover hemlock from the Pacific coast.

6. *Spruce,* to cover Eastern spruce; that is, the spruce timber coming from points east of Minnesota.

7. *Western Spruce*, to cover the spruce timber from the Pacific coast.

8. *White Pine*, to cover the timber which has hitherto been known as white pine, from Maine, Michigan, Wisconsin and Minnesota.

9. *Idaho White Pine*, the variety of white pine from western Montana, northern Idaho, and eastern Washington.

10. *Western Pine*, to cover the timber sold as white pine coming from Arizona, California, New Mexico, Colorado, Oregon and Washington. This is the timber sometimes known as "Western Yellow Pine," or "Ponderosa Pine," or "California White Pine," or "Western White Pine."

11. *Western Larch*, to cover the species of larch or tamarack from the Rocky Mountain and Pacific coast regions.

12. *Tamarack*, to cover the timber known as "Tamarack," or "Eastern Tamarack," from States east of and including Minnesota.

13. *Redwood*, to include the California wood usually known by that name.

IV. STANDARD SPECIFICATIONS FOR BRIDGE AND TRESTLE TIMBERS.

(To be applied to solid members and not to composite members.)

GENERAL REQUIREMENTS.

Except as noted all timber shall be cut from sound trees and sawed standard size; close grained and solid; free from defects such as injurious ring shakes and crooked grain; unsound knots; knots in groups; decay; large pitch pockets, or other defects that will materially impair its strength.

Standard Size of Sawed Timber.—Rough timbers when sawed to standard size, shall mean that they shall not be over $\frac{1}{4}$ in. scant from actual size specified. For instance, a 12 in. x 12 in. shall measure not less than $11\frac{3}{4}$ in. x $11\frac{3}{4}$ in.

Standard Dressing of Sawed Timbers.—Standard dressing means that not more than $\frac{1}{4}$ in. shall be allowed for dressing each surface. For instance, a 12 in. x 12 in. shall after dressing four sides, not measure less than $11\frac{1}{2}$ in. x $11\frac{1}{2}$ in.

STRINGERS.

No. 1. *Longleaf Yellow Pine and Douglas Fir.*—Shall show not less than 80 per cent. of heart on each of the four sides, measured across the sides anywhere in the length of the piece; loose knots, or knots greater than 1½ in. in diameter, will not be permitted at points within 4 inches of the edges of the piece.

No. 2. *Longleaf Yellow Pine, Shortleaf Pine, Douglas Fir, and Western Hemlock.*—Shall be square edged, except it may have 1 in. wane on one corner. Knots must not exceed in their largest diameter ¼ the width of the face of the stick in which they occur. Ring shakes extending not over ⅛ of the length of the piece are admissible.

CAPS AND SILLS.

No. 1. *Longleaf Yellow Pine and Douglas Fir.*—Shall show 85 per cent. heart on each of the four sides, measured across the sides anywhere in the length of the piece; to be free from knots over 2½ in. in diameter; knots must not be in groups.

No. 2. *Longleaf and Shortleaf Yellow Pine, Douglas Fir and Western Hemlock.*—Shall be square edged, except it may have 1 in. wane on one corner, or ½ in. wane on two corners. Knots must not exceed in their largest diameter ¼ the width of the face of the stick in which they occur. Ring shakes extending not over ⅛ the length of the piece are admissible.

POSTS.

No. 1. *Longleaf Yellow Pine and Douglas Fir.*—Shall show not less than 75 per cent. heart, measured across the face anywhere on the length of the piece; to be free from knots over 2½ in. in diameter, and must not be in groups.

No. 2. *Longleaf and Shortleaf Yellow Pine, Douglas Fir and Western Hemlock.*—Shall be square edged, except it may have 1 in. wane on one corner, or ½ in. wane on two corners. Knots must not exceed, in their largest diameter, ¼ the width of the face of the stick in which they occur. Ring shakes shall not extend over ⅛ of the length of the piece.

LONGITUDINAL STRUTS OR GIRTS.

No. 1. *Longleaf Yellow Pine and Douglas Fir.*—Shall show one face all heart; the other face and two sides shall show not less than 85 per cent. heart, measured across the face or side anywhere in the piece; to be free from knots 1½ in. in diameter and over.

No. 2. *Longleaf and Shortleaf Yellow Pine, Douglas Fir, and Western Hemlock.*—Shall be square edged and sound; to be free from knots 1½ in. in diameter and over.

LONGITUDINAL X-BRACES, SASH BRACES AND SWAY BRACES.

No. 1. *Longleaf Yellow Pine and Douglas Fir.*—Shall show not less than 80 per cent. heart on two faces and four square edges; to be free from knots over 1½ in. in diameter.

No. 2. *Longleaf and Shortleaf Yellow Pine, Douglas Fir, and Western Hemlock.*—Shall be square edged and sound; to be free from knots 2½ in. in diameter and over.

REPORT OF COMMITTEE S ON WATERPROOFING MATERIALS.

During the past year an attempt has been made to inaugurate the program outlined in the last report.

Sub-Committee A, which has charge of the investigations in connection with all non-bituminous waterproofing materials used as incorporated mixes with mortars or concretes or as surface washes, planned a series of tests, and enlisted the assistance of three well-equipped laboratories. Unfortunately the pressure of other work deferred the inauguration of the proposed tests until too late in the year to get as positive results at long periods as had been hoped for. Only recently records extending to three month periods have been received in full from two of the three laboratories, the other one being unable to complete the program of tests and only returning partial results.

In view of the absolute necessity for further corroboration before reporting any positive conclusions, it is deemed best to make this report only a general one of progress. As said last year, the chairman would welcome suggestions from any member of the full Committee as to possible tests to be undertaken, the program followed so far being the result of informal conferences between a few members, equipped to undertake the investigations and having special experience therewith.

The only conclusion possible at this time, from data so far obtained, indicate that the majority of waterproofing compounds examined under the jurisdiction of Sub-Committee A are no more effective than untreated properly proportioned mixes which certainly can be made absolutely waterproof by the use of proper materials and well proportioned mixes. It is entirely possible that some compounds do effect an improvement in badly proportioned mortars and concretes made up of inferior materials. Undoubtedly some surface washes are effective.

Through a misunderstanding the work of Sub-Committee B in charge of Bituminous Materials, has so far resulted in nothing on which to base a report, except of progress; it is hoped that another year will furnish results.

Respectfully submitted on behalf of the Committee,

W. A. AIKEN,
Chairman.

A. W. DOW,
Secretary.

REPORT OF COMMITTEE T ON THE TEMPERING AND TESTING OF STEEL SPRINGS AND STANDARD SPECIFICATIONS FOR SPRING STEEL

The Committe can only report progress at this time. Considerable work has been done, individually and collectively, but the more one does the more one finds there is to do.

Till very recently the testing of springs has been considered so simple that definite instructions seemed superfluous. This may hold true with helical and volute springs, which show a keen desire to follow the formulæ, but with elliptic springs however, as mentioned last year, the friction between the plates introduces an element of variation which seems to follow to neither rule nor reason.

In plotting tests of leaf springs, it is found that there is a wide difference in the height of the spring at specified load, depending upon whether the load was gradually applied or released from 50 per cent. to 100 per cent. overload. This difference will be from $\frac{3}{8}$ in. to $1\frac{1}{4}$ in. For this reason if a specification is submitted allowing $\frac{3}{16}$ in. over or under the specified height, the total allowance would be, not $\frac{3}{8}$ in. but from $\frac{3}{4}$ in. to $1\frac{5}{8}$ in., depending on the amount of friction in the spring. This is illustrated by Fig. 1, which is submitted to show the action of two springs AA and BB′ identical, except in that AA′ has 4 in. free height and BB′ 3 in. free height. If we consider that these springs have a specified load of 25,000 pounds and 1 in. height under that load, then both springs could be made to meet this height with the usual $\frac{3}{16}$ in. allowance either way, AA′ on a released load, and BB′ on an applied load. It is evident that if one of these springs is correct the other is not, though both would meet the ordinary specification.

Of equal interest and importance is that when the load is released from a spring there is no change in height for the first 3,000 to 6,000 pounds, depending somewhat on the capacity of the spring. This is often taken advantage of in testing springs to an open specification, in that the operation will compress the spring to the specified height as "G" in the diagram, then release if necessary to the specified load. The reverse is also true so that if the second spring was released from B′ to a height of 1 in. and then the specified load applied the spring would be balanced at "E."

As indicated in diagram submitted last year, if a spring at a fixed height "G" be submitted to shock, such as tapping the leaves with a hammer, part of the friction will be overcome, and the load will recede approximately a third the distance between the applied and released load lines. On the other hand if a spring under a uniform load as at "C" be submitted to a shock, such as tapping the leaves with a hammer, part of the friction will be overcome, and the height will recede approximately a third the difference between the applied and released load lines. For this reason a spring in service will always stand below the applied load line and above the release load line. Again in service, springs are sometimes submitted to as much as 60 per cent. overload, as was shown by investigations of Mr. Wm. Mussey of the Long Island Railway. This would result in springs standing, upon resuming normal load,

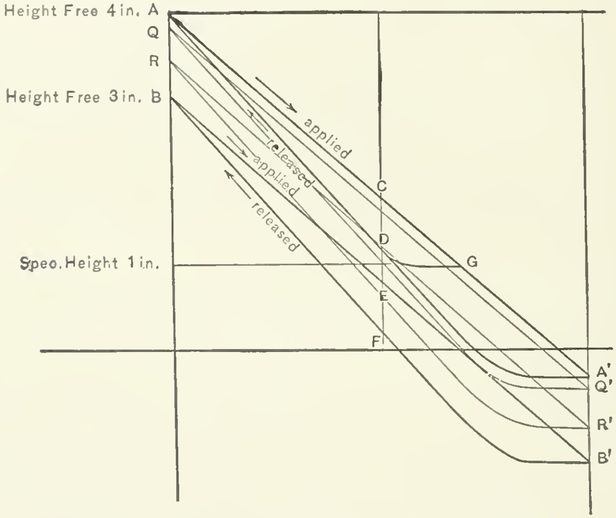

FIG. 1.—Variation in Testing Elliptic Springs.
Specified Load, 25,000 pounds.

near the released load line or from ⅛ in. to ½ in. below the original height. In locomotive service if all the springs are equalized together, this difference in height would matter little but if the extreme springs are cross equalized only, as is sometimes the case with the front set in switching engines, this increased set may lower the one end of the boiler, and by shifting the load cause permanent increased set or weak springs, which are always cause for replacement.

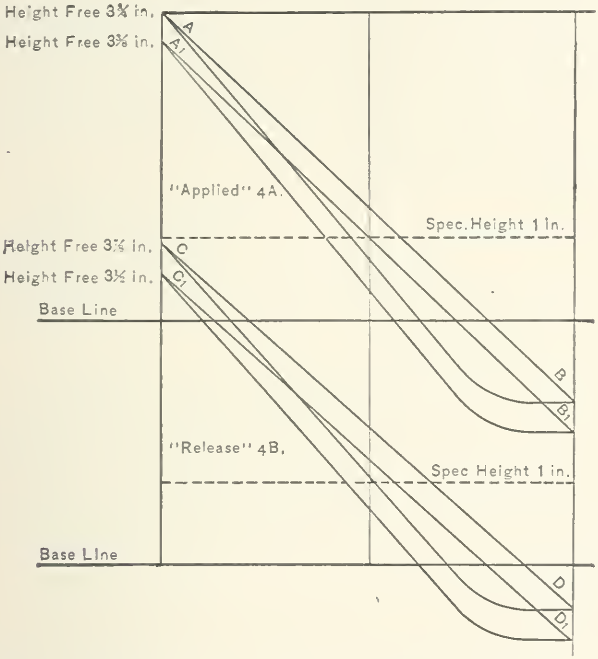

Fig. 2.—Comparison of Applied and Released Load Tests.
Specified Load, 25,000 pounds.

The Committee has compared during the year the action of springs in a surging machine, as compared with the rigid machines now in common use. It is found that after repeated surging the spring stands about one-third below the applied load height. By measuring this height on applied load line it was found to be from 12½ per cent. to 18 per cent. over load. It was suggested that 12½ per cent. overload would be close enough for practical use, but on further discussion it was decided that either the applied or released load test would be simpler and accomplish the same result.

The Sub-Committee on tempering has obtained bars of Bessemer, open hearth and vanadium steel and expects to have results along this line within a short time.

The Committee desires to submit the following tentative specification which covers both the applied and released load tests and would ask for as wide a discussion as possible at this meeting, and that members use the specification during the ensuing year and report results obtained.

TENTATIVE SPECIFICATIONS FOR STEEL SPRINGS.

PROCESS OF MANUFACTURE.

1. Steel for springs may be made by the open hearth and crucible process.

CHEMICAL PROPERTIES.

2. There will be two classes of spring steel which shall conform to the following limits in chemical composition:

	Elliptic and semi-elliptic.	Coil.
Carbon....................	.90 to 1.10	not under .90
Manganese shall not exceed...	.50	.50
Phosphorus " " ...	.05	.05
Sulphur " " ...	.05	.05

Bands will be made of wrought iron to A. S. T. M. requirements.

TEST PIECES AND METHOD OF TESTING.

3. At least 25 per cent. of each lot of shipment of springs selected at random, will be submitted to the following test:

4 (*a*). Springs, with ends of semi-elliptics supported on swinging or roller bearings, must not be less nor more than $\frac{3}{8}$ in. over specified height, under "applied" specified load, and must not take permanent set when free.

4 (*b*). Springs, with ends of semi-elliptics supported on swinging or roller bearings when released from one

and one-half times specified load, must not be higher nor more than $\frac{3}{8}$ in. lower than specified height, and must not take permanent set when free.

FINISH.

5. Plates must fit closely together at all times, and deflect uniformly under test loads.
6. Plates must be free from lamination and other defects and must not vary from card more than .03 in. in width, nor more than .02 in. in thickness.
7. Bands must not vary from card more than $\frac{1}{8}$ in. in width and $\frac{1}{16}$ in. in thickness, and must be free from injurious flaws and defects.
8. Length from center to center under specified load must not vary more than $\frac{1}{4}$ in. from card.

MARKING.

9. Each spring must be stamped on one side of band with maker's mark, and date made (month and year).

INSPECTION.

10. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Fig. 2 illustrates the difference between the two methods of testing. The release test will give a higher spring under all conditions, depending on the difference between the height under applied and released loads. In the present instance with an assumed difference of $\frac{5}{8}$ in. the release test would give a spring $\frac{1}{8}$ in. higher.

As there is considerable more work yet to be done, it is recommended that the Committee be continued another year.

Respectfully submitted on behalf of Committee,

J. A. KINKEAD,
Chairman.

DISCUSSION.

The President. THE PRESIDENT.—Gentlemen, this subject is before you. Since I am on my feet I would like to ask Mr. Kinkead if he knows what the carbon was in the vanadium steel.

Mr. Kinkead. MR. J. A. KINKEAD.—I have not been able to get an analysis of it yet.

The President. THE PRESIDENT.—We made some analyses of vanadium steel that was too low in carbon. They told us it was 40. The samples we worked on were vanadium and chrome, the chrome being about .40 per cent., the vanadium rarely above .2 per cent. But I was wondering whether vanadium low carbon steel was going to give us what we want. I don't know the difficulty of getting higher carbon vanadium. If the carbon goes up higher I think the concern would go away up in the air.

Mr. Stevenson. MR. A. A. STEVENSON.—There is a rather curious thing in regard to vanadium; that is, it acts very much better with some alloy, such as chrome. You can not get the same results from vanadium alone.

Mr. Lanza. MR. G. LANZA.—It may be worth while, in this connection, to state a few facts regarding our own experience in making tests of this kind, in connection with the thesis work of my students.

In the first of the three theses, viz., that by Mr. H. J. Macintire, the attempt was made to determine the modulus of elasticity, and the breaking strength and limit of elasticity of round tempered spring steel, both for tension and for torsion, and while some results were obtained, the greatest difficulty encountered was the fact that the steel was so hard that the jaws of the testing machines were incapable of holding it, so that they allowed slippage, and also the jaws themselves were destroyed. It appears, therefore, that some means should be devised for obviating this difficulty.

In the second thesis, viz., that of Messrs. H. V. Coes and C. A. Howard, an apparatus was placed upon one of the driving springs of locomotives in service, which would give a continuous record of the deflection of the spring, the object being to ascertain

Mr. Lanza.

the amount of overload of the spring in passing over frogs, diamonds, switches, and irregularities of track, that due to variation of speed, to application of the brakes, etc. Three springs were tested in this way, two of them in freight, and one in passenger service.

In one case, the spring was subsequently tested in the testing machine, to determine the load corresponding to the deflection. No surging test was made.

In the case of a 36-inch spring, in freight service with 17 leaves, each 44 x $\frac{3}{8}$ in., where the static load in service was 14,144 pounds the maximum deflection due to overload was 0.34 in. corresponding to a static load as shown in the testing machine of 3,500 pounds. The maximum negative deflection was 0.48 in., the difference between the greatest and least deflections being, therefore, 0.82 in.

For the other springs, similar results were obtained.

In the third thesis, viz., that of Messrs. E. B. Snow and E. D. Boles, no tests were made on the road, but tests were made, under tensile and under transverse stress, of the spring metal, before and after tempering, and also a test, in the testing machine, of an entire spring.

The results obtained showed clearly, that a great deal depends upon the precautions taken in the tempering and in the manufacture of the spring.

In the light of the above stated tests, it appears that there is considerable room for improvement, in many cases, (a) in securing suitable material, (b) in the precautions taken as to temperatures, etc., in the tempering, and the manufacture of the spring, and (c) that the overload, and also the variations of deflection in service, need to be taken into account in the design of the spring.

Mr. Souther.

MR. H. SOUTHER.—The automobile business is driving the spring maker to greater extremes than ever before, certainly in my experience. I see in the preliminary specifications presented by Mr. Kinkead something lacking as far as automobiles are concerned. For example, it is almost certain that if I were to draw specifications for automobile purposes to-day I should demand that the spring leaves be polished and, further than that, lubricated. It makes all the difference in the world in the riding

Mr. Souther. of the car. Also I do not believe that any static test as presented will suffice for the inspection of an automobile spring. I may be getting to be a bit cranky on dynamic tests. Static tests fail to measure the excellence of materials as far as automobile purposes go.

As to the quality of steel, that is very much in the air. So far carbon steel of good quality, very much as specified by Mr. Kinkead, if properly treated, does good work. But I want to say that it has not been properly treated nor uniformily treated in years gone by. There is one concern in the West that is going at it intelligently, very intelligently, so as to get not only better, but absolutely uniform treatment, and they are going so far as to use double treatment for the highest grade springs.

I look upon the treatment as being of more importance than the steel itself, variations in treatment will produce a good spring from rather ordinary steel, and will produce a rotten spring from very good steel. How such a Society as this can hope to control manufacturing processes I do not know. I have had that in my mind many times and tried to do it, but have found it impractical. The spring maker who has been in business thirty or forty years will promptly tell you that he knows a good deal more about it than you can ever hope to. And consequently I think a test must be devised that will be so good as to detect his weakness, if there be any weakness; I mean the weakness of improper treatment.

Now I hope that such a dynamic test can be incorporated in the specifications. I am not sure it is necessary for locomotive people to go to the extremes that the automobile people must, but I should think it would be a good thing if they did, just the same. The question of alloy steels has been brought up here already in the matter of vanadium. If the steel mentioned came from the American Vanadium Company it is safe to say it is chrome vanadium. I doubt very much if they put forth anything except chrome vanadium.

Analysis of imported French springs indicate the use of much silico-manganese steel. The same as is being imported into this country for spring purposes. Krupp is sending to this country chrome nickel for spring purposes; and I want to say that whenever chrome or nickel or silico-manganese is used, that the carbon content seems to be much less; than proposed by the committee, the rare elements, so to speak, seeming to accentuate the influence of the carbon to such an extent that lower carbon is possible. But I believe that a good high-grade carbon steel, properly and carefully heat-treated, will make a most excellent spring. I sincerely hope that the Committee will consider some kind of fatigue or endurance test. The impact test may replace that, but certainly something besides the static test is desirable. **Mr. Souther.**

MR. KINKEAD.—In regard to static load of springs I wish to say that arrangements are being made to make a drop test as well a static test of the same type of springs. Both tests will be made and compared, just as we have compared the surging test with the rigid machine, and we find that they are in some way identical. The surging test gives a middle point between the test we get with the rigid machine and the static test. **Mr. Kinkead.**

MR. H. DEH. BRIGHT.—The subject of automobile springs in relation to the question of "Pounds per inch of deflection" has been touched on in a rather interesting manner. We find that an automobile spring carries a load of about 500 pounds per inch deflection, while with a locomotive spring, it would appear that 14,000 pounds per one inch deflection is the proper figure. The question of width must of course be taken into consideration, and the allowable load per one-inch deflection should be given for one inch of width, as it is self-evident that a spring 6 inches wide will carry twice the load of a spring 3 inches wide, with the same results, as the 6-inch spring is practically the equivalent of two springs 3 inches wide placed side by side and in the same band. **Mr. Bright.**

With relation to the influence of design on the life of a spring, we have some interesting results from two practically twin roads. We found that the replacements on the road where the springs were of a proper design were in the ratio of one against the replacement of twenty-one on the road where the design was not correct. This replacement ratio of one to twenty-one was obtained by reducing both roads to the same number of locomotives for the same period of time. All springs on both roads were made from the same quality of steel, at the same time, and by the same process.

Several designs of spring, of which a great many broke on the road having the excessive failures, were corrected by making a spring of a lower carrying capacity and thinner plates, thereby obtaining a greater deflection per unit of load.

Mr. Bright. I therefore feel that a load limit per one-inch of deflection as suggested by Mr. Kinkead is the solution of excessive failure.

Mr. Brown. MR. WILLIAM L. BROWN.—The gripping apparatus which we constructed for testing springs at Altoona consisted of an octagonal steel block, four sides of which were serrated with 90 degree grooves, spaced about $\frac{1}{4}$ inch apart. On the four serrated sides were a series of movable jaws, which extended down and around the last coils at the ends of the spring. In the center of the spring was a tapered block and the jaws when they were screwed home, pressed the wire against this tapered block. I may say that we only tested the large eight-inch outside coils of the spring and we found this apparatus very effective. Two holders were provided and fastened to the stationary and pulling heads of the machine by suitable bolts. Our tests were made by adding slight increments of loads, varying at first by 500 pounds, until we knew something more about the springs, and then by 1,000 pounds, starting at 500 pounds initial load; the deflection being measured by an ordinary vernier scale to $\frac{1}{100}$ of an inch. We have taken and stretched an ordinary spring which has a deflection between the free and solid heights under compression of about five inches, to a distance of over 18 inches deflection without visible crack or failure of any kind. It seems to me the difficulty is that our springs, as we receive them, are too soft and that we could safely increase the temper to a very much harder and stiffer steel than we use at present. I think the fact that we stretched these springs to such a great deflection would render a spring perfectly safe to use, even if tempered much harder.

Our formula, which is Reuleaux formula, for helical springs, we use with a torsional modulus of elasticity of 12,600,000; and when we figured back from the length of the spring and its deflection the actual modulus for each of the different working loads, we found it in every case to be very much lower than the figure used in our calculations, in some cases it being as low as 6,000,000. We also took some of these springs and pulled them a second time. That is, they would have a certain permanent set after the first test and we would start with that permanent set included in the new length of spring and test them a second time. In that case we raised the modulus from 3,000,000 to 4,000,000, or from 6,000,000 to about 9,000,000 or 10,000,000. We also ran into a very peculiar condition, and that was, these first springs which we tested, had all been subjected to a compressive test when they were originally made, and when we reversed conditions and stretched the springs we found that there was a negative set; that is, we had to remove the original compressive set and change it to a tensile set. We found from $\frac{1}{4}$ to $\frac{3}{8}$ and $\frac{1}{2}$ and as much as $\frac{3}{4}$ of an inch set, under very light loads, with these conditions. **Mr. Brown.**

MR. SOUTHER.—I should like to say that I have yet to find a well-marked elastic limit in any piece of well-tempered spring steel. From the beginning to the end of the stress-strain diagram no straight line is to be found. That brings up the possibility of measuring the temper of a spring by the modulus. To do this a sufficient number of investigative tests should be made on normal springs. Assuming that the normal fiber stress for a leaf spring or other is 20,000 pounds per square inch, it will doubtless be found as a result of such tests that the modulus of elasticity at 20,000 pounds per square inch will fall within certain limits. Any spring so tempered that when tested the modulus of elasticity falls without these limits is either too hard-tempered or too soft-tempered. **Mr. Souther.**

During the discussion it has been quite rightly stated that the tempering operation is all important, and it strikes me that the temper can be controlled in some such manner.

Another point that has not been touched upon in this discussion is the number of leaves in the semi-elliptic or full-elliptic springs. The tendency in the automobile business is to use the greatest possible practical number for any given thickness of spring. Easy riding is certainly obtained in this way.

MR. LANZA.—I should like to ask both Mr. Brown and Mr. Souther whether in their determinations of the modulus of elasticity, they deducted the permanent set from the strain, as it is only by so doing that the true modulus of elasticity can be found. **Mr. Lanza.**

MR. SOUTHER.—In my observations I measured the total deflection or elongation in ten inches by means of a rolling-pin extensometer. The shape of the curves was widely varying, but by no possible stretch of the imagination could any straight line be found. All were curves from beginning to end, and the observations were consistent. I am very glad of the thought to get permanent set and will make surge tests. But of course we are **Mr. Souther.**

Mr. Souther. confronted in testing carbon spring steel with what Prof. Lanza brought out, and that is the matter of grips. It is exceedingly difficult, and more than that, it is difficult to prepare a specimen. I attempted to take a full width of spring leaf and was not satisfied with the results and therefore annealed some leaves, cut them down a quarter of an inch on each side, so as to give a substantial reduction of area throughout the ten inches, and then I got what I considered consistent results. But you see that means that if the manufacturer is permitted to prepare a specimen separate from an actual leaf prepared for a spring, and he is foxy, he will give you what he likes.

The Chairman. THE CHAIRMAN.—Did Mr. Brown take out the set?

Mr. Brown. MR. BROWN.—I did not take out the permanent set. I considered only the total deflection.

Mr. Kinkead. MR. KINKEAD.—Replying to Mr. Souther I would say that the two curves A and A_1 (Fig. 2) show very accurately the difference between the spring as it is ordinarily and after it is oiled. We find approximately the same difference when we test a spring just as it comes from the shop and after oiling.

I want to refer to Mr. Souther's statement in regard to hard riding springs. We had a man connected with the Company, who said, "If the thing breaks, it breaks because it is not strong enough. Make them strong." I have worked on the question of breaking springs about two years now and I thought I would shut up on it until we got a little more evidence. I see it is brought out again. We have four instances which point quite conclusively to the reason for the breaking of semi-elliptic springs, and double-elliptic springs, as far as that is concerned. In one case I remember that we had a spring which had a total load of 19,000 pounds. The deflection of that spring was .95 inch. The spring failed in service continually and was one of the bugbears that Mr. Bright referred to. The load on the spring was 21,000 pounds, calculated. The load per inch deflection was 19,000 pounds. The spring was submitted by a spring company, and they made a duplicate spring which had 3,000 pounds less strength and vastly more flexibility. Instead of having 19,000 pounds per inch deflection it had 16,000 pounds; instead of having 21,000 pounds specified load it had 18,000 pounds. It was weaker than the other spring, but it carried the engine without difficulty. In other

Mr. Kinkead.

words, if they had made it any stronger they would have increased the trouble, and when they did make it weaker they decreased the trouble. This spring was made of 5 x $\frac{7}{16}$ in. plates, ten in number. The spring which was used to replace it had sixteen plates 4 x $\frac{3}{8}$ in. The same thing came about in another road. They had a spring identical with this one, which had only nine plates, with a load of 18,000 pounds. They had some trouble in connection with this spring and returned it to the spring company, and in replacing the spring they used seventeen plates 5 x $\frac{5}{16}$ in. This gave a lower load per inch deflection—12,500 pounds approximately. The second spring was entirely satisfactory, although several thousand pounds weaker than the other one. We have had several instances of the same thing. That leads us to the thought that the rate per inch deflection or flexibility of springs is the measurement of the breakage of the spring. In other words, when we get a high load per inch deflection we approximate the rigid beam, and the rigid beam under repeated loads will break earlier than a flexible beam.

In regard to automobile springs, if Mr. Souther increases the number of plates but decreases the thickness, he will get good results. If he keeps the same thickness I think he will get in trouble.

Mr. Rodgers.

MR. S. M. RODGERS.—I should like to ask Mr. Kinkead why he omitted the elements of silicon in the specifications. In making certain grades of spring steel we have always regarded a certain percentage of silicon, especially with an increase in manganese, quite essential to making a good lively spring. Such steels, however, call for special heat treatment to obtain the best results. Some steel manufacturers object to adding silicon to their steel, claiming that it causes piping. Our experience does not confirm this claim.

Mr. Kink

MR. KINKEAD.—As regards the silicon content of steel, nearly all the current specifications give the maximum, but no minimum; and we thought there was no danger of their putting in silicon unless it was specified.

The President

THE PRESIDENT.—What is the pleasure of the Committee on Springs as to the specification? Are you prepared to have it submitted to letter-ballot?

Mr. Kinkead.

MR. KINKEAD.—I would not like to have it submitted to

Mr. Kinkead. letter-ballot as yet, but would like to have it tried by the members during the year and then reported at the next meeting. There are some questions—the question of applied and released loads. I have been working on the released load for a year and a half and have had no trouble from the spring companies. They are all willing to use it and have no trouble in making measurements. I believe it gives fairly good results. Nobody has tried the applied load, and it was recommended that it might be advisable to use the applied load, and therefore that was inserted.

Mr. Bright. MR. BRIGHT (by letter).—Referring to Mr. Kinkead's statement that the applied load test had not been tried as yet, I feel that I should state that this method of testing has been in use for many years. It is used to-day by practically every manufacturer of springs in America, and by all railroads in testing their own springs, with the exception of three or four systems who use the release-load test. The applied-load test is not an experiment or a new departure but rather the standard method of approved spring testing.

REPORT OF COMMITTEE U ON THE CORROSION OF IRON AND STEEL.

Committee U, in studying the corrosion of iron and steel, finds that a test which is sometimes employed to determine the tendency of a given sample to corrode, is to place the same in a strong mineral acid and measure the rapidity with which it dissolves. Much of the work already accomplished indicates that there is a direct connection between the rapidity of solution in acid and natural corrosion. Other experiments show the test to be very inconsistent. In order to decide the validity and trustworthiness of this acid test it is necessary that the results of all investigators who may employ it should be comparable, and to this end the Committee makes the following tentative suggestions as to the conditions under which the test should be carried out:

Acid Test for Iron and Steel.

Samples to be tested are first stamped with suitable marks for identification, and are then accurately machined to a standard size (2 inches in length, $\frac{1}{2}$ inch in width and 1–16 inch in thickness).

The samples should be cut longitudinally in the direction in which the metal was rolled. A hole $\frac{1}{8}$ inch in diameter is drilled in each sample about $\frac{1}{4}$ inch from one of the ends.

Samples are polished first with No. 00 emery paper and finally with flour emery. The polishing should be done as much as possible so that the polish marks run at right angles to the direction in which the metal was rolled. After polishing, the test pieces should not be handled with the fingers or allowed to come in contact with dirt or grease of any kind.

The test pieces should then be weighed carefully to four decimal places on a chemical balance, and are then strung on a glass rod with a double reverse right angle bend at each end, which will allow the pieces to be suspended in a relatively large beaker or other suitable dish, so that their upper edges will be submerged to $\frac{1}{4}$ inch below the surface of the liquid. The glass rod should be only slightly less than $\frac{1}{8}$ inch in diameter, and the distance between any two adjacent test pieces when suspended in the acid should not be less than ½ inch.

The acid should be exactly 20 per cent. H_2SO_4 (1.144 specific gravity at 15° C.).

The test pieces are immersed in this acid for one hour, an approximately sustained temperature of 15° C. being maintained by any suitable cooling device, such as a large outside container of cold water.

At the end of exactly one hour's immersion the test pieces are quickly removed from the acid, well rinsed with running water, wiped as dry as possible and kept for one hour in a desiccator over sulphuric acid before weighing.

The results should be recorded as percentage loss, calculated on the original weight of the sample.

Note 1.—It has been shown that the corrosion of the sample is not directly proportional to the area exposed. Hence it is essential in making comparative tests that a standard size be adopted.

Note 2.—Should the samples for investigation be less than 1-16 inch in thickness, the other dimensions should be adhered to as closely as possible.

Note 3.—The physical condition of the surface of the sample is found to materially affect the rapidity of its solution. It is therefore desirable to finish all samples in the same way.

Note 4.—The strength of sulphuric acid chosen is that concentration which contains approximately the maximum number of hydrogen ions and which experiments have shown to be the most suitable.

Note 5.—It is necessary that the samples be suspended in a reasonably large body of acid in order that the ferrous sulphate formed by the reaction may sink to the bottom or be otherwise dissipated through the solution, so that the concentration of the acid in the immediate vicinity of the samples be not materially changed.

Note 6.—The greatest care should be taken to employ only chemically pure sulphuric acid. It has been shown that very minute traces of arsenic, for example, seriously retard the rapidity with which iron is dissolved.

Submitted on behalf of the Committee,

ALLERTON S. CUSHMAN,
WM. H. WALKER, *Secretary.* *Chairman.*

THE CORROSION OF IRON.

By Allerton S. Cushman.

Before we can expect to make progress in solving the difficulties attendant upon the rapid corrosion of iron and steel, it is essential that the fundamental causes and the resulting reactions which attend the formation of rust should be thoroughly understood. The first important fact which impresses the investigator of this subject is the great variation exhibited by different specimens of iron and steel to corrosive influences. This is true, not alone in regard to samples of different kinds of metal, such as wrought iron, charcoal iron, Bessemer and open-hearth steels, but also of different specimens of one kind of metal made by the same process in different mills, or even at different times in the same mill. The reasons for these variations in the quality of iron and steel, as far as resistance to corrosion is concerned, have not been thoroughly understood, and therefore manufacturers have not known in most cases how to proceed in order to accomplish any improvements in this special field.

Three separate theories which, though they all more or less overlap, nevertheless involve distinctly different reactions, have been advanced and strenuously defended, in the effort to furnish an explanation for the rusting of iron. These may be stated as the carbonic acid, the hydrogen peroxide, and the electrolytic theories.

The carbonic theory is the one most generally held and usually presumes that without the interaction of carbonic or some other acid, the oxidation, or better, the hydroxylation of iron can not take place. According to this theory the process of rusting is a cyclical one. Iron is attacked by carbonic acid, which forms ferrous carbonate. The ferrous carbonate is then acted on by water and oxgyen with the formation of iron hydroxide and the liberation of the original carbonic acid. The reactions which express this may be written:

$$2Fe + 2H_2CO_3 = 2FeCO_3 + 2H_2$$
$$2FeCO_3 + 5H_2O + O = 2Fe(OH)_3 + 2H_2CO_3.$$

Although the above explanation is sufficiently plausible and in spite of the fact that carbonic acid as well as other acids do act a part in the ordinary rusting of iron, it will presently be shown that iron readily oxidizes not only when carbonic acid is entirely absent, but also in dilute alkaline solutions. It is only when the hydroxyl ions supplied by an alkaline solution have reached a certain concentration that rusting is entirely prohibited.

The carbonic acid theory was founded originally on the investigations of Crace Calvert,* as interpreted by Crum Brown.† It has also more recently been vigorously defended by Moody,‡ who insists that with water and oxygen quite free from carbonic acid, iron can not rust. This view is however not shared by Dunstan, Jowatt, and Goulding,§ or by Whitney‖ or Cribb,¶ all of whom give experimental evidence to show that rusting takes place rapidly in the absence of carbonic acid, provided liquid water and oxygen are present. The experiment of Dunstan and his co-workers was so carefully carried out that there seems to be no doubt that if carbonic acid plays any role whatever, it is an unimportant one and that rusting can go on with extreme rapidity in its absence.

As a matter of fact if the believers in this theory are correct, the rusting of iron would be an unknown phenomenon in any atmosphere which did not, like that of this earth, contain about four one-hundredths of one per cent. of carbonic acid. The writer has performed critical experiments which have recently been published in detail, which confirm the opinion that the presence of carbonic acid is not necessary in order to produce rapid oxidation of iron, or ordinary rust.**

It has long been known that rusting is inhibited and that polished iron will remain bright indefinitely in all sorts of alkaline solutions, provided they are sufficiently concentrated. This is also true of all solutions of salts of strong bases and weak acids which hydrolyze to an alkaline reaction. This fact has been eagerly seized upon by the adherents of the various theories which have been advanced, as it can be made to fit in more or less well with them all. Thus, alkalis absorb carbonic dioxide, and therefore carbonic acid is prevented from carrying on its work of destruction. The added fact that fully saturated bicarbonate of soda also provides full protection to iron, even in fairly dilute solution, which would seem to be a stumbling block, has not shaken the faith of the devout believers in the carbonic acid theory.

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* *Manchester Lit. Phil. Mem.*, 1871, 5, 104.

† *Jour. Iron and Steel Inst.*, 1888, 129-131.

‡ *Proc. Chem. Soc.* (London), 1906, 22, 101.

§ *Jour. Chem. Soc.* (London), 1905, 87, pt. 2, 1548.

‖ *Jour. Am. Chem. Soc.*, 1903, 25, 394.

¶ *The Analyst*, 1905, 30, 232.

** U. S. Dept. Agr. Office Public Roads, Bull. 30.

The writer's experiments have shown that it is only when the hydroxyl ions have reached a certain concentration that the attack upon iron is inhibited. The critical discussion of this point will be found elsewhere, but the conclusion seems certain that the presence of carbonic acid is not a condition which inevitably produces the rusting of iron.

Another theory which has been advanced by Dunstan, Jowatt and Goulding, and which has gained some adherents, is that iron can not rust unless hydrogen peroxide is formed as a transition step in the reaction. As hydrogen peroxide is more or less unstable in alkaline solutions, it is claimed that iron should not rust when immersed in them. The added fact that the rusting of iron is actually accelerated by solutions of potassium iodide, iodine, dilute potassium permanganate, and other substances which also destroy hydrogen peroxide, must apparently be accepted as exceptions which prove the rule.

Solutions of chromic acid and its soluble salts, such as the chromate and bichromate of potash, inhibit the rusting of iron immersed in them. As solutions of chromic acid and its salts oxidize and destroy hydrogen peroxide, this fact was used by Dunstan and his co-workers to strengthen the peroxide theory. According to this theory the chemical reactions involved in the rusting of iron should be written:

$$Fe + O_2 + H_2O = FeO + H_2O_2$$
$$2FeO + H_2O_2 = Fe_2O_2(OH)_2.$$

The theory appears to derive some confirmation from the fact that delicate tests for hydrogen peroxide have been obtained during the slow oxidation of zinc and some other metals. On the other hand, in the case of iron, these same delicate tests obstinately refused to reveal even its transitory presence during the ordinary process of rusting. The theory has been criticized by Divers,* Moody,† and Cribb,‡ the first named having pointed out that it is not tenable to argue that because such substances as chronic acid and alkalis gradually destroy hydrogen peroxide, they must prevent its formation. For instance, ferrous sulphate is oxidized by free chlorine, but it does not prevent manganese dioxide and hydrochloric acid from reacting when brought together in its presence. Moreover, if the formation of hydrogen peroxide was a necessary stage in the rusting of iron and this is inhibited by certain substances which destroy hydrogen peroxide, why is not the inhibition extended to strong reducing agents generally? The theory is an interesting and suggestive one, but in the author's opinion is not supported by the facts.

Although the peculiar inhibitive action of solutions of the chromates has been noted by Dunstan, it does not appear to have been heretofore systematically studied. The writer has attempted to determine the concentration necessary to produce complete protection. A number of polished strips of two different samples of steel were immersed in bichromate solutions of increasing concentration, contained in tubes which were left quite open to the air. There were twelve tubes in each series, ranging by regular dilutions from tenth-normal down to ten-thousandth normal. At the end of two months the last four tubes showed graded rusting with accumulation of ferric hydroxide. No rusting had occurred in any of the solutions above tube No. 8, which contained six-hundred and fortieth normal bichromate, a strength corresponding to about 8 parts of the salt in 100,000 parts of water, or about 2 pounds to 3,000 gallons. Since solutions of bichromate do not hydrolyze with an alkaline reaction, but on the contrary are usually slightly acid, some other explanation must be found for this remarkable phenomenon. On first thought it would seem a paradox that a strong oxidizing agent should have the effect of preventing the oxidation of iron, and yet this is precisely the case. If, however, the initial cause of rusting is the hydrogen ion, it is possible to believe that under certain conditions oxygen would prove the most effective of all inhibitors. As has been stated, Dunstan, Jowatt and Goulding have claimed that this peculiar action of chromic acid and its salts is due to the fact that they destroy hydrogen peroxide. This explanation is not satisfactory, as has been pointed out, and it is fair to inquire whether the electrolytic theory is capable of furnishing a solution of the problem. Furthermore, it will be shown that additional evidence can be brought forward which can not be made to apply to any other theory.

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* *Proc. Chem. Soc.* (London), 1905, 21, 251.

† *Jour Chem. Soc.* (London), 1906, 89-90, 720.

‡ *Analyst*, 1905, 30, 225.

The writer has observed that if a rod or strip of bright iron or steel is immersed for a few hours in a strong (5 to 10 per cent.) solution of potassium bichromate, and is then removed and thoroughly washed, that a certain change has been produced on the surface of the metal. The surface may be thoroughly washed and wiped with a clean cloth without disturbing this new surface condition. No visible change has been effected, for the polished surfaces examined under the microscope appear to be untouched. If, however, the polished strips are immersed in water it will be found that rusting is inhibited. An ordinary untreated polished specimen of steel will show rusting in a few minutes, when immersed in the ordinary distilled water of the laboratory. Chromated specimens will stand immersion for varying lengths of time before rust appears. In some cases it is a matter of hours, in others of days or even weeks before the inhibiting effect is overcome.

The passivity which iron has acquired can be much more strikingly shown, however, than by the rusting effect produced by air and water. If a piece of polished steel is dipped into a 1 per cent. solution of copper sulphate, a ten-second immersion is sufficient to plate it with a distinctly visible coating of copper which can not be wiped off. A similar polished strip of steel which has been soaked over night in a concentrated solution of bichromate and subsequently well washed and wiped, will stand from six t ten ten-second immersions in 1 per cent. copper sulphate before a permanent coating of copper is deposited.

The first explanation of this phenomenon which naturally presents itself is that a thin film of either oxide or chromate has been formed on the surface of the metal. It is almost inconceivable, however, if such a film is formed, that it cannot be seen with the aid of a microscope. There is evidence which appears to indicate that no such film of oxide is formed. It is easy to cover polished iron with a visible film of oxide by simply flaming it gently in a Bunsen burner. Such films do not succeed in protecting the iron either from the rusting or the copper sulphate test. Still more convincing than this is the fact that if a polished surface which has been rendered passive by immersion in bichromate is heated to 100° C. for some hours, its passivity disappears, and it again behaves in a normal manner. None of the oxides or chromates of iron are in any sense volatile compounds, so that if a solid but invisible film is really formed, it is in some manner dissipated by heat. Further than this, a chromated strip of iron which is kept in a vacuum soon loses its passivity, whereas a similar strip kept under ordinary conditions remains passive for long periods.

The passivity of iron was discovered by Keir in 1790.* Since the phenomenon is produced only by strong oxidizing agents or by galvanic contact when oxygen can separate on the iron, it was explained by Faraday, Wiederman and others† as due to a thin oxide film. From the evidence given above, however, it seemed that the passivity of iron was better explained as a polarization effect produced by the separation and retention of oxygen on the surface of the metal. If the rusting of iron is due primarily to the action of hydrogen ions, iron in the condition of an oxygen electrode should be more or less well protected from electrolytic attack.

Keir‡ observed that polished iron which had been immersed in red fuming nitric acid was altered in some manner so that its power of precipitating silver and copper from their solutions was inhibited, and this occurred, in the discoverer's own words, "without the least diminution of metallic splendour or change of colour." In the writer's experience red fuming nitric acid does not produce the passive condition as successfully as solutions of chromic acid and its salts. Mugdan discussed the passivity acquired by iron which was immersed in fuming nitric or sulphuric acids and concluded that it was not due to the formation of an oxide film, but was a true passivity in the sense of an ennobling (Veredlung) of the metal,* accompanied by a low electrical potential.

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* *Phil. Trans.* (London), 1790, 359.

† Dammer's *Anorg. Chem.*, 1893, 3, p. 294.

‡ *Loc. cit.*, p. 216.

Moody† asserts that potassium bichromate prevents the formation of rust, owing to the fact that it slowly dissolves iron and its hydroxides. He observed that the addition of ammonia to solutions of chromic acid and its salts which had been allowed to act on iron, produced precipitates of hydroxide. This point has been carefully investigated by the writer, with the following results: Iron which is free from manganese is not attacked by solutions of bichromate, even if boiled for days in a flask fitted with a return condenser. Manganese is, however, readily soluble in bichromate solutions and therefore iron rich in manganese yields a sufficient amount to the solvent to produce a small amount of brownish manganese hydroxide when the bichromate solution is poured off, made slightly ammoniacal, and allowed to stand. If metallic manganese is boiled in bichromate solutions it dissolves readily and subsequent addition of ammonia produces an abundant precipitate of brown manganese hydroxide.

If polished iron is allowed to stand for some time in standard tenth-normal potassium bichromate solution, the oxidizing strength of the latter as measured by its titration value is slightly reduced without the solution of the iron or the production of any visible effect. Under the same conditions a standard solution of neutral potassium chromate is slightly reduced with the appearance of a small amount of chromic hydroxide. In fact all the evidence obtainable points to the abstraction by the iron of some of the available oxygen of chromic acid and its salts without the formation or solution of iron oxide films.

In order to show beyond doubt that an oxygen electrode is formed by immersing iron in a strong solution of bichromate, the following experiment was made. Two polished steel electrodes were prepared and chromated by immersion for a number of hours in a strong solution of potassium bichromate. The prepared electrodes were then thrust tightly through a rubber stopper which closed a Jena flask, which was then filled with pure freshly boiled distilled water. The electrodes were then attached to the poles of a primary battery at about 2 volts potential. At the end of half an hour, although no visible change had occurred, the electrode which was connected to the zinc pole of the battery had lost its passivity, the other retaining it. It might still be objected that if a film of oxide had been formed, it might suffer reduction at the negative pole; it is, however, very easily shown that electrodes which have been oxidized by gentle heating are not reduced under the conditions of this experiment.

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* *Ztschr. Elektrochemie*, 1903, 9, 454.

† *Loc. cit.*, p. 214.

Wood* in 1895 commented on the power of paints and pigments containing certain oxidizing agents, notably potassium bichromate and lead chromate, to form on iron and steel surfaces a thin coating of oxide which so effectually protects the metallic surfaces from corrosion that after the removal of the paint the metal still resists atmospheric effects for a long time, as well as the stronger effect of immersion in sea water or acidulated waters, sulphurous and other vapors. This action, Wood adds, is very obscure and not thoroughly understood; but the fact remains, and extended experiments in this field only demonstrate its presence and usefulness. The author has not been able to find, however, that the soluble chromates have ever been put in use as rust inhibitors.

The oxide film theory has been held for many years to account for the passivity of iron, but in the writer's opinion the protection afforded by certain oxidizing agents is electro-chemical and not mechanical.

From the standpoint of the modern theory of solutions, all reactions which take place in the wet way are attended with certain readjustments of the electrical states of the reacting ions. The electrolytic theory of rusting assumes that before iron can oxidize in the wet way, it must first pass into solution as a ferrous iron. The subject has been interestingly treated by Whitney,† who discussed it from the standpoint of Nernst's conception of the source of electromotive force between a metal and a solution. When a strip of metallic iron is placed in a solution of copper sulphate, iron passes into solution and copper is deposited, this change being of course accompanied by a transfer of electrical charge from the ions of copper to those of iron. Hydrogen acts as a metal and is electrolytically classed with copper in relation to iron. If, therefore, we immerse a strip of iron in a solution containing hydrogen ions, an exactly similar reaction will take place, iron will go into solution and hydrogen will pass from the electrically charged or ionic to the atomic or gaseous condition. In such a system the solution of the iron and therefore its subsequent oxidation must be accompanied by a "precipitation" or setting free of hydrogen. It is very well known that solutions of ferrous salts as well as freshly precipitated ferrous hydroxide are rapidly oxidized by the free oxygen of the air to the ferric condition, so that if the electrolytic theory can account for the original solution of the iron, the explanation of rusting becomes an exceedingly simple one.

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* *Amer. Soc. Mech. Eng. Trans.*, 1895, 16, 671.

† *Loc. cit.*, p. 212.

As iron has been shown by Whitney, Dunstan, and the writer to rust in the presence of pure water and oxygen alone, the electrolytic theory as a fundamental cause of the wet oxidation of iron must stand or fall on the determination of one crucial question, viz., Does iron pass into solution, even to the slightest extent, in pure water? If iron does dissolve, the electrolytic theory is so far satisfactory; if it does not dissolve, we must conclude that the oxygen finds some way of directly attacking the metal.

Almost every one will admit that in the case of impure iron, with its unhomogeneous physical and chemical constitution, electrolysis will supervene, but it must be remembered that we are now concerned with the underlying cause of the wet oxidation of iron regardless of its state of chemical purity.

According to the dissociation theory, even the purest water contains free hydrogen ions to the extent of about 1 gram in 10,000,000 liters. If iron dissolves in the purest water it should be by interchange with hydrogen, and as Whitney* has pointed out, pure water is to this extent an acid.

The experiments of the writer confirm those of Whitney in showing that in pure water iron is slightly dissolved as ferrous hydroxide, while in the system iron, pure water and oxgyen the rusting of iron goes on rapidly.

The electro-chemical or electrolytic theory of the rusting or corrosion of iron, whether it appears in the form of pitting or as an even coating, is as follows: If iron or steel is brought into contact with water, either pure or natural, iron goes into solution by replacing the hydrogen ions that are present, and if oxygen is present the ferrous ions are oxidized with the formation of ferric hydroxide in the form of rust. Any substance which increases the concentration of the hydrogen ions in the water, such as carbonic, sulphuric, or other acids, will stimulate corrosion. On the other hand, any substance which decreases the concentration of the hydrogen ions, or in any manner prevents the interchange of the electrostatic charge between the metal and the hydrogen ion, will inhibit corrosion. It follows from this that the rusting of iron is primarily a hydroxylization rather than an oxidation, and the oxygen does not directly attack the surface of the metal in the wet way or at ordinary temperatures.

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* *Loc. cit.*, p. 212.

Perhaps the most conclusive proof that the electrolytic action must take place before rusting can occur is given by an experiment of Moody's, which has been repeated and confirmed by the writer. Dunstan and his co-workers claimed that when iron is placed in hydrogen peroxide the metal is rapidly oxidized with formation of ferric hydroxide. As Moody has pointed out, commercial hydrogen peroxide is invariably acid and contains impurities. In perfectly pure hydrogen peroxide bright iron will catalytically disengage oxygen and retain its polished surface unacted upon. It is not an easy matter to prepare a perfectly neutral pure solution of hydrogen peroxide, but it can be accomplished by two fractional distillations at 85° C. under reduced pressure (700 mm.) of commercial dioxygen. Before distilling the second time the solution should be made barely alkaline with a few drops of one-hundredth normal potassium hydroxide. In a pure neutral 1 per cent. solution of hydrogen peroxide thus prepared Moody's observation was confirmed. Iron immersed in the solution remained bright for a protracted period. Hydrogen ions do not exist in a pure neutral solution of peroxide, therefore neither solution of iron nor electrolysis can take place. If the flask containing the specimens covered by pure hydrogen peroxide solution is connected to a vacuum pump, oxygen is disengaged freely and boils off the surface of the metal without the appearance of the slightest speck of rust.

As has already been stated, in order that rust should be formed iron must go into solution and hydrogen must be given off, in the presence of oxygen or certain oxidizing agents. This presumes electrolytic action, as every iron ion that appears at a certain spot demands the disappearance of a hydrogen ion at another, with a consequent formation of gaseous hydrogen. The gaseous hydrogen is rarely visible in the process of rusting, owing to the rather high solubility and great diffusive power of this element. Substances which increase the concentration of hydrogen ions, such as acids and acid salts, stimulate corrosion, while substances which increase the concentration of hydroxyl ions inhibit it. Chromic acid and its salts inhibit corrosion by producing a polarizing or dampening effect which prevents the solution of iron and the separation of hydrogen.

We pass now to an inquiry in regard to whether it is possible to produce a visible demonstration of electrolytic action taking place as rusting proceeds. Early in this investigation the writer observed that whenever a specimen of iron or steel is immersed in water or a dilute neutral solution of an electrolyte to which a few drops of phenol phthalein indicator has been added, a pink color is developed. It the solution is allowed to stand perfectly quiet it will be noticed that the pink color is confined to certain spots or nodes on the surface. The pink color of the indicator is a proof of the presence of hydroxyl ions and thus indicates the negative poles. Many persons who are interested in the metallurgical problems connected with the iron and steel industry may not be familiar with the modern theory of indicators and therefore an explanation of the manner in which phenol phthalein shows the presence of hydroxyl ions by the formation of a pink color will not be out of place. Phthalic acid was first prepared by Laurent in 1836 by the oxidation of naphthalene and was first called naphthalinic acid. It was afterwards shown that the compound was not directly related to the naphthalene structure and Laurent changed the name to phthalic acid, the derivatives of which became known later as phthaleins. Phenol phthalein is a product which is formed by the condensation of two molecules of phenol or carbolic acid with the anhydride of phthalic acid. It is in its nature so weak an acid that it is not dissociated in solution and as the molecule is colorless, no color is seen when it is added to a perfectly neutral solution. If, however, an alkali is added the corresponding salt of the weak acid is formed, which immediately dissociates with the formation of a metallic cation and the strongly rose colored organic anion. Thus all hydroxides of basic elements will show the pink color in solution, even when present in only the slightest excess. On this account phenol phthalein is an exceedingly delicate indicator of the presence of hydroxyl ions in a solution. Since the phenol phthalein* shows only the nodes where solution of iron and subsequent oxidation can not take place, Prof. W. H. Walker suggested the addition of a trace of potassium ferricyanide to the reacting solution, in order to furnish an indicator for the ferrous ions whose appearance mark the positive poles. If iron goes into solution ferrous ions must appear which, with ferricyanide, form the well known Turnbulls blue compound. Going a step further, Walker suggested stiffening the reagent with gelatin and agar-agar, so as to prevent diffusion and preserve the effects produced. For this combined reagent which indicates at one and the same time the appearance of hydroxyl and ferrous ions at opposite poles, the writer has suggested for the sake of brevity the name "ferroxyl." The reagent is prepared and used in the following manner: A hot solution of the purest agar-agar or gelatin in distilled water is carefully neutralized with one-hundredth normal potassium hydroxide, using phenol phthalein as the indicator. When exact neutrality has been obtained a few drops of a dilute solution of potassium ferricyanide is added. When a layer of the reagent is poured into a dry Petri dish floating in ice water it should stiffen into a firm jelly in a few minutes. The polished specimens are laid carefully on the jelly and flooded with another layer of the reagent. After the preparation has hardened it should be covered and set away in a cool dark place. In the course of a few hours the negative and positive zones will begin to develop in red and blue. If the reagent has been properly prepared the color effects are strong and beautiful. In the course of a few days the maximum degree of beauty in the colors is obtained, after which gradual deterioration sets in.

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* Phenol phthalein is used to a large extent in empirical tests, as in dairying, the cement industry, soil examinations, etc., etc. The name is cumbrous if not alarming to the layman, while the chemist does not need to be reminded of the origin of the compound each time he has occasion to speak of it. A shortening of the name of the indicator to "phenolin" would be a decided improvement.

The blue positive nodes show sharp outlines in a photographic reproduction, while the pink negative nodes appear with hazy outlines. In the pink zones, as would naturally be expected, the iron remains quite bright as long as the pink color persists. In the blue zones the iron passes into solution and continually oxidizes with a resulting formation of rust. Even the purest iron develops the nodes in the ferroxyl indicator, but impure and badly segregated metal develops the colors with greater rapidity and with bolder outlines. This result would of course be expected, as in pure iron the formation of poles would be conditioned by a much more delicate equilibrium than in impure iron, where changes in concentration of the dissolved impurities would stimulate the electrolytic effects. Even so-called chemically pure iron contains small quantities of dissolved gases, and it is not improbable that even slight variations in the physical homogeneity of pure iron will occasion the electrolytic effects which are made visible by this delicate reagent. The characteristic appearances which are obtained in this test are shown in Figs. 1, 2, 3 and 4.

It has been noted by a number of investigators that different samples of iron and steel do not rust in the same way when subjected to the action of water and air. While some samples show localized electrolytic action, as indicated by deep pitting, others become covered with a more or less homogeneous coating of hydroxide, which shows little or no tendency to localize in spots or nodes. The question naturally arises, in what respect do these two methods of rust formation differ? Fig. 5 exhibits an effect which is frequently observed in the ferroxyl tests. When the colors first developed two dark blue nodes formed at the opposite ends of the test piece, with a large pink area in the center, where for a time the metal remained quite bright. Very shortly, however, the poles changed, the pink central area disappeared and gave way to a large blue node which enveloped three quarters of the test piece, with a small opposed pinkish spot. Again and again a reversal and change of poles took place, and at least five such changes are clearly shown in the photograph. As a result of this action the metal strip was rapidly covered over its entire surface with the same superficial, loosely adherent coating of hydroxide which is obtained in many cases when samples of iron and steel are allowed to rust under a layer of water. It is presumable that as the surface of the metal is eaten into by the solution of the iron at the positive poles, a new condition of equilibrium occurs, resulting in changes and even reversals of the positive and negative nodes. This would indicate that in the case of metals which suffer from local action or pitting, the segregation conditions are of a different nature from those which exist in the case of metals which rust more evenly. A rough analogy may be drawn by imagining an imperfect mixture of black and white sand, the respective grains of which may lie in streaks, spots and layers, or may tend to arrange themselves in some more or less uniform relation to each other. The best demonstration that the rusting and corrosion of iron and steel in all its forms is essentially an electrolytic phenomenon is afforded by the fact that it is not possible to find a specimen of such purity that no trace of positive and negative nodes will be formed in the ferroxyl indicator.

When a section of rolled metal, such as sheet or plate, is immersed in water, if the electrolytic theory is correct rusting must take place with the establishment of positive and negative spots or areas. At the positive points iron will pass into solution and be rapidly oxidized to the loose colloidal form of ferric hydroxide which is characteristic of rust formed under these conditions. It is a well known fact that colloidal ferric hydroxide will move or migrate to the negative pole if subjected to electrolysis. We may therefore consider the possibility of two separate effects that may be produced, viz., when a positive center is surrounded by a negative area, and vice versa. These two conditions may be graphically represented by the two circles A and B shown below:

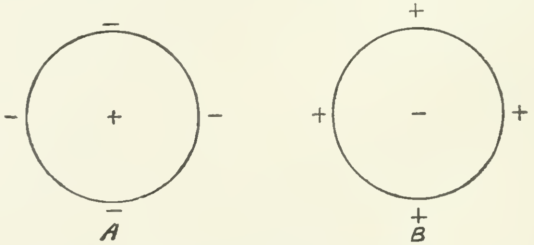

Diagram Illustrating Electrolytic Action on the Surfaces of Iron and Steel.

Now as rusting proceeds we should expect in the case of A that the ferric hydroxide would be piled up in a crater formation while the metal is eaten out at the center. In the case of B the effect would be reversed, and while the metal would be attacked in the surrounding area the hydroxide would be piled up in a cone at the center. That this is precisely what is taking place whenever a sheet of metal rusts under water a low power microscope very clearly shows. In Figs. 6 and 7 very good examples of crater and cone are shown as they formed upon the surface of rusting steel. Fig. 8 shows the etching effect on strips of iron and steel that have been immersed in the ferroxyl reagent. The electrolytic effects which have been active on the three samples are beautifully illustrated. Figs. 9 and 10 show the general similarity between freshly formed rust-spots and the actual pit holes which formed on a boiler tube in service.

The evidence advanced in the preceding pages appears to the writer to confirm the conclusion that the whole subject of the corrosion of iron is an electro-chemical one which can be readily explained under the modern theory of solutions. It is an undeniable fact that some irons and steels suffer corrosion very much more rapidly than others, and the underlying causes for these differences constitute one of the important problems of modern metallurgy.

Although the discussions brought forward in this paper are mainly theoretical in their nature, it is quite apparent that they also have a direct practical bearing. Before advance can be made in overcoming the difficulties in the way of manufacturing iron which shall have the maximum resistance to corrosion, as well as the preservation of the metal under the conditions of service, the underlying causes must be thoroughly understood. If we accept the electro-chemical explanation of the corrosion of iron there can be no doubt that conditions which inhibit electrolytic effects also inhibit corrosion, and vice versa. The purer the iron in respect to certain other metals which differ electro-chemically from iron, and the more carefully lack of homogeneity and bad segregation is guarded against, the less likely are the electrolytic effects to become serious. These points constitute the essential problems which confront the manufacturer who desires to make a product which shall have a high resistance to corrosion. The user and consumer, however, are interested in the protection of the various types of merchantable iron and steel which are available under market conditions at the present time. In short, protective coatings and palliative methods of treatment are in greater demand to-day than ever before. From the standpoint of the electrolytic theory many suggestions for experiment under the conditions of service present themselves. The fact that hydroxyl ions inhibit the rusting of iron has been made practical use of for a long time past, and it is not unusual to add caustic alkalis to boiler waters for this reason. This, however, frequently causes trouble from foaming, and as Cribb* has shown, if an insufficient amount of alkali is present the pitting effect is accentuated rather than inhibited. This observation is in accord with the theory that the hydroxyl ions must reach a certain concentration, which varies with different conditions, before entire prohibition of the electrolytic effects is obtained. At concentrations much below those necessary to prohibit electrolysis the action is similar to that obtained by adding a neutral electrolyte to the water, *i. e.*, the electrolytic effects are stimulated. There should be many cases, however, where the property of alkalis to inhibit corrosion could be made of more practical use than has been done. Whenever iron posts or standards are set directly in the ground instead of being imbedded in concrete, the liberal use of slaked lime should be beneficial.

The expedient of using metallic zinc in boilers to overcome the local electrolytic effects in the iron, by producing a still greater electrolytic effect at the almost exclusive expense of the more positive zinc, is well known and has been in use for a long time. Although the theory on which the use of zinc for this purpose is based is sound, great difficulty has been encountered in maintaining good metallic contacts between sufficiently large surfaces of the two metals under the conditions which maintain in a boiler. From what has been shown in regard to the inhibitive action of the chromates it is not improbable, since such dilute solutions prevent electrolysis and corrosion, that the addition of small quantities of bichromate to boiler waters would be highly efficacious in preventing the rapid pitting which has caused so much trouble. It has lately been reported that steel boiler tubes used on vessels fitted with turbine engines suffered corrosion to the point of failure in from two to four months' service.* This was found to be due to the fact that the steam, containing perhaps volatile acids, impinging on the bronze turbine blade, carried copper into solution and through the condensers into the boiler. Since iron does not change places with copper in dilute solution containing bichromate, it is possible that here again this salt would be found of practical value. That this statement is correct can easily be shown. If a bright piece of iron is immersed in a solution of copper sulphate so dilute as to show only a faint bluish tinge, the iron will nevertheless turn dark from precipitated copper in a very few moments. If now potassium bichromate is added in only just sufficient amount to give a yellowish instead of a bluish tinge to the solution, iron will remain bright and copper will not be deposited.

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* *Loc. cit.*, p. 214.

The experiment has been made of keeping iron and steel in dilute boiling solutions of bichromate, through which a current of air is bubbled, for protracted periods, and as long as the strength of the solution was equal to or above one or two pounds of bichromate to 1,000 gallons of water no rusting has ever taken place. There would therefore seem to be no reason why potassium bichromate should not come into use as a boiler protective. The application of the various inhibitors in the priming coats of paints and other protective coverings has already been to some extent made use of, and it would appear that slightly soluble chromates should be theoretically the best protectives for the first application to iron and steel surfaces.

A very widespread impression prevails that charcoal iron and puddled wrought iron are more resistant to corrosion than steel manufactured by the Bessemer and open-hearth processes. It is by no means certain that this is invariably the case, but it would follow from the electrolytic theory that in order to have the highest resistance to corrosion a metal should either be as free as possible from certain impurities, such as manganese, or should be so homogeneous as not to retain localized positive and negative nodes for a long time without change. Under the first condition the irons would seem to have the advantage, but under the second much would depend upon care exercised in manufacture, whatever process was used.

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* *Eng. News*, 1907, 57, 426.

The evidence appears to be conclusive that the corrosion of iron in all its forms is primarily due to hydrogen ions. The ability of various samples to resist the attack of an acid of a standard strength may turn out to bear some relation to resistance to corrosion under service conditions. A great variation in resistance to acid corrosion is shown by different specimens of both iron and steel. An investigation of this subject is being made in connection with the work of Committee U of the Society. Carelessly made and poorly segregated metal will be easily attacked, no matter what it may be called or what method was used in its manufacture. As has already been pointed out, there are two lines of advance by which we may hope to meet the difficulties attendant upon rapid corrosion; one is by the manufacture of better metal, and the other by the use of inhibitors and protective coverings. Among the various inhibitors none so far studied yields such effective results as chromic acid and its salts.

Acknowledgment is made to *The Iron Age* for the cuts used in this paper.

INFLUENCE OF STRESS UPON THE CORROSION OF IRON.

By Wm. H. Walker and Colby Dill.

The importance of as full an understanding as is possible of the factors which enter into the cause and prevention of the corrosion of iron and steel, has been demonstrated anew by the recent action of the Executive Committee of this Society in the appointment of a Committee to study this old, yet unsolved problem.

Of the many factors which are supposed to enter into corrosion, there is one which has been investigated almost entirely by engineers to the practical exclusion of the man with a chemical training. This is the influence of stress upon the electromotive force of iron and hence upon its corrosion. The fact that in riveted sheet iron work the rivets and the plate often show a marked difference in their rate of corrosion has been frequently noted. Portions of bridge members sometimes show a selective corrosion. The barbs of so-called barbed-wire fencing generally corrode more rapidly than the main wires. These differences in corrosion have been explained by some writers of repute as due to a difference in potential set up in the two members by the unequal strain to which they are subjected. The most recent work upon the protection of iron from corrosion is "Rustless Coatings,—The Corrosion and Electrolysis of Iron and Steel," by M. P. Wood.* Under the head of "Corrosion Increased by Stress" the author defends the above theory and supports his view by quotations at length from three investigators. The first of these is Thomas Andrews, F.R.S.,† who in 1894 published the results of an extensive piece of work from which he concluded that when a piece of iron or steel is strained, for example, until it has an elongation of 20 per cent. in three inches, this strained portion is less readily attacked than the portions beyond the jaws of the machine, or the unstrained portion. He states "the unstrained portion was electropositive, answering to the zinc of a galvanic battery." While Wood in "Rustless Coatings" gives Andrews' work in considerable detail, he misquotes his summary of results in that he states that the "strained metal was electropositive." This version agrees with Wood's opinion, but is diametrically opposite to the meaning and text of Andrews.

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* John Wiley & Sons, 1904.

† Proceedings Institute Civil Engineers (British), 118, 356 (1894).

The next authority quoted is Prof. D. C. Jackson, who reported some work done at the University of Wisconsin by Carl Hambuechen. Although in his report Prof. Jackson gives full credit to Hambuechen, Wood ignores this fact and treats it as a separate investigation. Hambuechen* followed in part the method of Andrews, but with more refined methods. He arrived, however, at diametrically opposite results and concluded that the strained metal is electropositive and hence will corrode more rapidly than the unstrained metal.

From an electro-chemical standpoint both these investigations are unsatisfactory. Andrews did not prepare his two specimens in the same manner, and used an electrolyte (common salt solution) which, owing to the high polarization phenomena incident to its use, must give erroneous results. Hambuechen unfortunately used as an electrolyte a ferric chloride solution which on account of the action of metallic iron upon it also gives abnormal results.

In an investigation by Richards and Behr† some experiments upon the effect of strain upon the potential of iron were made. The authors conclude from their work that the magnitude of the changes produced is smaller than is usually supposed. The data are, however, so scanty and the results, as the authors point out, so irregular that no conclusions of value can be drawn.

The present investigation was undertaken with the hope of throwing some light upon the question of the sign and magnitude of the potential changes caused by straining a piece of iron, particularly below the elastic limit, and therefore of the change in the tendency of strained iron to corrode.

The magnitude of the increase in potential which one would expect to be produced can be easily computed on the assumption that the energy stored up in the specimen below the elastic limit is all available as potential. Some very pure commercial iron (Swedish charcoal iron) was obtained and tested in the usual manner to determine the modulus of elasticity and elastic limit. The diameter of the specimen was about 0.25 inch. Elongations were measured by means of a micrometer which could be read with fair accuracy to ten-thousandths of an inch. Electrical contact was used to insure parallel conditions at each reading. The results of this test showed the modulus of elasticity, or ratio of stress to strain, to be 28,000,000 and the elastic limit about 16,500 pounds per square inch. A second experiment gave concordant results. From this data, the amount of work which would be done upon a cubic inch of iron if it were strained to its elastic limit would be

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*Bulletin, University of Wisconsin, Engineering Series, No. 8. (1900.)

† Publication of Carnegie Institution, Washington, 1906.

$$w = \int_{0}^{17000} f dl$$

where w = work done in inch pounds,
f = stress applied at each instant,
l = strain produced.

Since $\frac{f}{l} = 28000000$, $dl = \frac{1}{28000000} df$.

Substituting this value, $w = \frac{1}{28000000} \int f df$.

Integrating and substituting limits,

$$w = \frac{17000 \times 17000}{2 \times 28000000} = 5.16 \text{ inch pounds.}$$

The maximum amount of work which it is possible to do upon one cubic inch of soft iron by stretching it to its elastic limit is therefore 5.16 inch pounds. This is equal to 5.83 joules and one cubic inch of soft iron weighs approximately 126 grams, assuming the specific gravity to be about 7.7. The work done in joules per equivalent is therefore

$$5.83 \times \frac{1}{126} \times \frac{56}{2} \text{ or } 1.30 \text{ joules;}$$

and the change in electromotive force which would be expected is $\frac{1.30}{96600}$ or 0.0000134 volt. The magnitude of this change is thus very small; its direction should be positive because it is the manifestation of energy stored up in the metal.

APPARATUS.

The well known method of Poggendorf was selected as the most suitable for the measurement of such small potential changes as seemed likely. The galvanometer was an unusually good instrument of the D'Arsonval type. Its internal resistance was about 1,000 ohms and it readily indicated corresponding to a change of potential of 0.00002 volt. The galvanometer was hung upon a Julius suspension to protect it from the annoying vibration caused by the heavy testing machines close at hand.

The specimens of iron used were made from two lots of exceptionally pure Swedish charcoal iron, in the form of rods $\frac{1}{4}$ and $\frac{1}{2}$ inch diameter. The manipulation of specimens of these diameters is much more convenient than in the case of specimens of fine wire. The stresses can be determined more accurately. The question of inequality in the distribution of the strain over the cross-section of the specimen due to the cold flow of the metal is of slight importance under the stresses which were measured, *i. e.*, below the elastic limit. The bars were cut in lengths of about 18 inches and the central portion reduced in a lathe for a distance of about one inch until a zone of bright new metal was exposed. This band was smoothed in the lathe, first with a file and finally with emery cloth of moderate fineness. It is necessary to have the length of the reduced portion of the specimen at least one inch in the case of the half-inch specimens in order to eliminate the effect of the portion of larger diameter upon the strength of the reduced portion. Tests made at the Watertown Arsenal upon rolled plate indicate that the strength of the metal at the reduced section may be increased as much as 20 per cent. where the length of the reduced portion is very small. By making the reduced portion greater than twice the diameter, it is fairly certain that the condition of the metal at the center of the reduced portion is the same as it would be if the bar were of the same diameter throughout. With the exception of a narrow zone about $\frac{1}{4}$ inch wide at the middle, the bars were covered with a waterproof coating to insulate the metal from the solution except at the desired point. A number of insulating substances were tried—rubber, wax, paraffin, and collodion, but the most satisfactory was ordinary shellac applied in two or more thick coats. The shellac is not allowed to dry perfectly hard and so it remained sufficiently elastic to stretch with the iron. Electrical contact with the iron was made by soldering, in the case of the $\frac{1}{4}$-inch specimens, and by means of a machine screw fitting a tapped hole in the end of the larger specimens. The form of cell was suggested by the one used by Richards and Behr. It consisted of a central tube about three inches long and one inch internal diameter open at both ends. To this were bound by means of adhesive tape three smaller tubes of the same length closed at the bottom. The bottom of the central tube was closed by a rubber stopper, carefully cleaned, through which the iron bar projected so that the reduced portion came at the middle of the tube. The central tube containing the specimen was filled with ferrous sulphate and then the three outer tubes were filled, one with ferrous sulphate and the other two with potassium chloride. All four tubes were then connected by means of siphons. The siphon of the normal calomel electrode dipped into the last KCl tube. These precautions were successful in preventing the diffusion of the $FeSO_4$ into the tube containing the normal electrode; not even a trace of iron was found in the latter after six weeks of constant use. The $FeSO_4$ solution was protected from air by a layer of paraffin oil carefully washed to remove traces of alkali or acid. It had been standing over very finely divided pure metallic iron in an atmosphere of hydrogen for six months, so that it was absolutely neutral.

It was found impossible to use testing machines operated by power, as the rapidly moving belts produced such a strong statical charge upon the machines as to make potential measurements quite out of the question. A testing machine operated by hand was found to be less convenient but quite as satisfactory in every other respect.

METHOD OF TESTING.

When everything was ready for the test, the specimen was lightly rubbed with fine emery to remove traces of oxide formed while the shellac was drying, inserted in the cell and the latter filled with ferrous sulphate and potassium chloride in the appropriate tubes. The siphons were then filled and inserted and the specimen placed in the testing machine. Here it was allowed to remain at rest until the electromotive force was constant to 0.0001 volt over a period at least as long as the test would last. The initial electromotive force was always higher by several millivolts than the final constant value, probably due to an oxygen film on the surface of the metal.

The specimens were first placed under a slight load in order that there might be no delay by reason of adjusting the wedges. A large number of pieces of iron were broken, but the results of but one typical experiment will be given. These are shown in Fig. 1. The load was put on uniformly and the potential dropped very slowly until, at a stress of about 31,000 pounds per square inch, the electromotive force had decreased 0.9 millivolt.* When the machine was stopped at this point, the beam of the machine sagged. When stress was again applied the potential rose suddenly 3.9 millivolts and when the machine was stopped, it dropped to its former value in 15 seconds, then sank more slowly to a minimum and then started slowly to rise again. As the load was put on a second time, the character of the change was similar to the first,—the same sharp rise followed by an abrupt fall when the machine was stopped, then a slower fall and then a rise to a constant value. The magnitude of this sudden rise depended upon the rate at which the stress was applied. A slight difference was that in the second and third loadings, the sharp rise did not take place until several seconds after the loading had commenced. The final value after fracture was in this case about 8 millivolts higher than the initial value. In this plot, time in minutes is plotted as abscissæ because

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* The result of stress up to the elastic limit in seven other runs was as follows:

Mark	Decrease in e. m. f.	Stress at which e. m. f. begins to increase.
9	0.0000	31000
10	0.0000	29000
11	0.0002	29000
12	0.0000	20000
13	0.0001	25000
14	0.0000	30000
15	0.0001	24600

it is practically impossible to determine the actual stress when the specimen has begun to "draw out" under stress approaching the breaking stress.

The potential, after fracture, of the following six specimens was carefully noted and when constant was measured. The original and final values, together with the differences, are:

Mark.	Material.	P_1	P_2	$P_2 - P_1$
5	Mild Steel	0.7329	0.7310	—0.0019
6	Swedish Iron	0.6927	0.6993	+0.0066
10	" "	0.7117	0.7165	+0.0048
11	" "	0.7224	0.7223	—0.0001
15	" "	0.7206	0.7282	+0.0076
20	" "	0.7182	0.7259	+0.0077

These potentials are all the potentials of the whole cell, *i. e.* Fe, $FeSO_4$, KCl, Hg. The potential of the iron electrode alone may be found by subtracting the value of the calomel electrode, 0.5620 volt at the temperature of experiment, from the values given. The results thus obtained agree with the work of Richards and Behr very closely.

The cause of the abnormal rise observed at high stresses was next considered. Change in temperature suggested itself as the most probable cause, although iron under these conditions has been shown to have a negative temperature coefficient. In order to duplicate as nearly as possible the thermal conditions which obtain in the iron electrode, a device was used whereby there was a continual flow of heat from the electrode to the solution. A hole about $\frac{1}{8}$ inch in diameter was drilled throughout the length of one of the electrodes. The upper end was joined by a rubber tube to a reservoir directly above, holding about two liters of hot oil. This was allowed to flow down through the electrode at a rate determined by the desired rise in temperature of the iron. It was evident that a rise of temperature produced a decided *decrease* of electromotive force. This fall of potential due to rise in temperature explains the fact that the dotted curves in Fig. 1 fall below the normal potential of the iron bar.

If the sudden rise in potential above the elastic limit is caused by temperature changes in the electrode, then, since iron has a negative temperature coefficient, the specimen must cool off as the breaking load is approached. Such a phenomenon, though highly improbable, is perhaps conceivable. Experiment showed, however, that there is a continuous rise in temperature from the elastic limit to the breaking load.

An experiment was also made with normal ferric chloride as electrolyte to see if this change in potential below the elastic limit also occurred. The specimen was prepared in identically the same manner as the previous ones. Soon after immersion in the ferric chloride it became coated with bubbles of hydrogen and the surface lost its metallic lustre and grew black. The potential rose rapidly during the first and second days. On the third and fourth days the potential was not measured. On the fifth day it had risen from 0.5279 volt to 0.6638 volt and was very constant. Scraping the specimen by means of a sharpened wire produced a decrease of 0.0031 volt. The next day (the sixth) the bar was pulled nearly to fracture. The potential decreased gradually 0.0006 volt from 1,200 pounds stress per square inch to 32,600 pounds—the yield point. Here the potential rose, as in all previous cases, but the subsequent behavior was irregular. This experiment confirms the previous ones with ferrous sulphate as electrolyte and makes it still more probable that the variations in potential

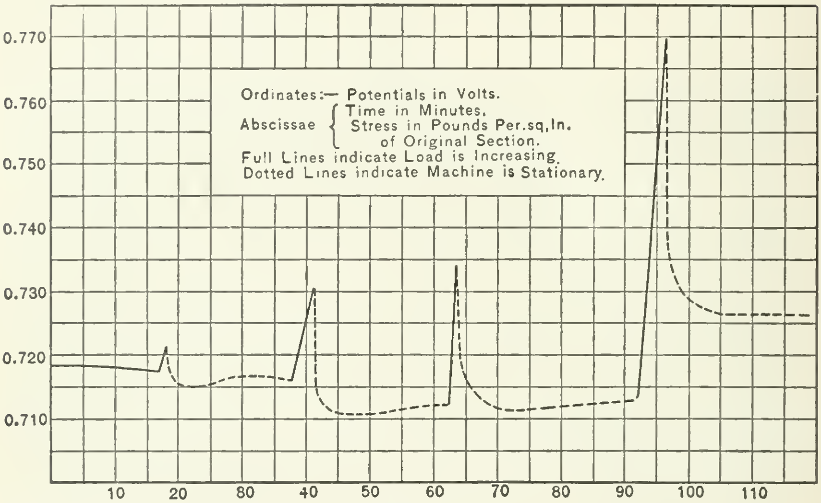

FIG. 1.

below the elastic limit, observed by Hambuechen, were caused by something other than stress.

If there is a permanent difference in electromotive force between a strained and an unstrained piece of metal, it should be apparent in the case of hard drawn wire when compared with the same wire annealed. A number of samples of steel wire in its strained condition were obtained and portions of each sample carefully annealed in a vacuum. In almost every case a difference of potential was observed between the annealed and unannealed specimen. But further investigation showed that as great, and frequently greater, differences existed between the different portions of the *same wire,* both in the strained and in the annealed condition.

SUMMARY.

The results of the foregoing experiments may be summarized as follows:

1. The magnitude of the potential changes suffered by soft iron when tested in a tension machine below the elastic limit, is exceedingly small. In the majority of cases it was less than 0.0001 volt. The maximum change was 0.0004 volt. This change can have no appreciable effect upon corrosion.

2. The change, when great enough to be measured, was negative, *i. e.* the strained metal had a slightly less tendency to corrode than the same metal unstrained.

3. Somewhere above the elastic limit, the potential rises suddenly several hundredths of a volt. The magnitude of the increase depends upon the rate of straining and ceases abruptly when the straining ceases.

4. Measurements upon specimens under torsional stress give results similar to those obtained from tension tests.

5. Out of a considerable number of specimens strained to breaking, the potential of six reached a constant value shortly after fracture. The difference between the initial and final potentials varied from —0.0019 volt to +0.0077 volt.

We conclude, therefore, that even beyond the elastic limit the corrosion of iron is not greatly affected by stress.

DISCUSSION.

The President. THE PRESIDENT.—I cannot forbear saying how charmingly the theory of these two papers on the subject of corrosion fits in with what has been practically the text of the Committee on Preservative Coatings ever since it was started. As we gradually began to get data indicating what we could do to protect iron and steel from corrosion, it apparently centered around this point: If you can so cover your metal that you keep the oxygen out there will be no corrosion. Apparently the experiments referred to in the two papers which you have listened to give an absolute reason why, and it looks as though the future was going to leave us these two problems: Either make the metal so there will be no difference of potential in any parts of it or cover it with something that will keep the oxygen out.

Mr. Wickhorst. MR. M. H. WICKHORST.—I wish to refer to some experiments we have in the C., B. and Q. R. R. Laboratory somewhat along the same line and in connection with the work of the Committee. If we take borings, we will say of a piece of rail steel and put them in a fermentation tube such as bacteriologists use, with distilled water or salt solution, we will get an evolution of gas collecting in the closed limb of the tube. That will occur even if we take care to keep away the atmospheric oxygen, there will be this evolution of gas which will also have a marked alkaline reaction to phenolphthalin, showing the presence of a hydrate of some sort. In the case of distilled water this must be ferrous hydrate. Now if we make an experiment with pure iron wire, such as we use in the laboratory for standardizing solutions, we do not get this evolution of gas. Apparently under those conditions the metal is so pure that the action does not occur. This all fits in very nicely with the explanations we have heard, that the impurities, or such conditions as may produce polarization, or differences of potential, cause a larger evolution of gas.

Mr. Cushman. MR. A. S. CUSHMAN.—I want to speak in behalf of your Committee U, on the Corrosion of Iron and Steel. Although we are not ready to make a final report, I want to call attention to the fact that we have developed three different methods by which it is possible that we may get advance information as to the corrosion resisting quality of different metals. First, the acid test, which I spoke of last night, which may possibly be proved useful. Second, Dr. Walker's method, which any one who has a chemical laboratory can carry out. I mean by this the paraffin block method of measuring the potential on the surface of specimens of iron and steel. **Mr. Cushman.**

The amount of hydrogen given off is in direct relation to the amount of rust that can be formed, therefore Mr. Wickhorst's experiment offers a third method which may possibly be used with borings as well as specimens with machined surfaces.

ON THE HEAT TREATMENT OF MEDIUM CARBON STEEL.—THE EFFECT OF RATE OF COOLING ON STRUCTURE.

By William Campbell.

In a former paper (Vol. VI, p. 211) the subject of the heat-treatment of high carbon steels was dealt with, and the changes which occur in the two constituents, pearlite and cementite were described.

In medium carbon steels of 0.40 to 0.50 per cent. carbon in their normal condition, we find two constituents, ferrite or pure iron, and pearlite or the eutectoid, a mixture of pure iron and iron carbide, cementite. The ferrite surrounds the grains of pearlite and a section shows a network of ferrite with a mesh of pearlite. The reason for this structure is because at temperatures above the critical points the steel exists in the form of a solid solution (which we call austenite) with a granular structure. As the temperature falls to the upper critical point, Ar_{2-3}, each grain becomes saturated with ferrite, which is thrown out of solution with fall of temperature. The whole being solid, the ferrite naturally collects around the outside of each grain, etc. At the lower critical point, Ar_1, the residual austenite (0.9 per cent. carbon) breaks down into the eutectoid, pearlite. Hence the structure consists of a network of ferrite with a mesh of pearlite.

Heating ordinary rolled steel bars to temperatures below the critical point, Ac_1, reduces the strength and increases the ductility. Whilst the size of grain remains unaltered thereby, the structure of each grain of pearlite alters, changing from the "sorbitic" or unsegregated condition to the coarsely laminated or highly segregated condition through a regular series, regulated by the temperature and time of heating.

Heating to the lower critical point, Ac_1, refines the grain of the pearlite. On heating to the upper critical point, Ac_{2-3}, the ferrite disappears being dissolved in the solid solution, austenite, which is formed when pearlite "transforms" on passing the lower critical point, Ac_1. But the higher the temperature of heating above Ac_1 the coarser will be the resulting grain of the pearlite. Hence we find that the steel has the finest structure where these changes balance, viz., just below Ac_{2-3}.

On the other hand, when we are dealing with material with a very coarse structure, as, for example, unannealed castings or overheated steel (Figs 1 and 29 to 36) the ferrite will have to be completely dissolved to refine it. Hence our refining temperature will be at Ac_{2-3}. Of course a second heating to Ac_1 will further refine the pearlite.

In general the higher the temperature of heating above the critical points, the coarser will be the structure of the steel, and this coarseness affects the ductility more than the strength.

If the material be slowly cooled after reheating to the critical points or above, another change besides that of grain size is noticed. The relative amount of ferrite will have increased enormously. This is well shown in Figs. 1 and 2. In Fig. 1 (x 45) we have a section of a 6-inch square ingot as cast; carbon about 0.45 per cent. The structure is so coarse that parts of three grains only can be seen. The lighter ferrite occurs in patches in, as well as in the form of envelopes round, the darker etching grains of pearlite. The relative amounts of ferrite and pearlite are nowhere near 1 to 1 as they ought to be if the pearlite contains 0.9 per cent. carbon which theory demands. On heating to just above the critical point Ac_1 and slowly cooling in the furnace (in a reducing atmosphere to prevent decarburization) the structure shown in Fig. 2 (x 45) was obtained. The texture is very fine and the relative amounts of ferrite and pearlite are now about equal. The lighter patch shows that the ferrite has not been completely refined, which would have occurred had the temperature been raised to Ac_{2-3}. This, however, would have produced a slightly coarser grain in the rest of the section.

A second example has been taken from rolled material. Several sections of 8-pound rails were polished and examined, similar pieces were heated to just above Ac_1 and slowly cooled, which produced as before an increase in the relative amount of free ferrite. Fig. 3 (x 45) shows the structure on the underneath of the head of a rail containing about 0.38 per cent. C., 0.80 per cent. Mn. After heating, the structure was found to be as in

Fig. 4. Whilst the temperature was not high enough to refine the ferrite and obliterate the structure due to the original rolling, the increase in total free ferrite is marked. In Fig. 5 (x 45) is shown a view from near the center of the head of a rail with 0.4 per cent. C. 0.8 per cent. Mn, whilst Fig. 6 shows the same after heating. Complete refining has occurred, with the usual increase in ferrite content.

Sauveur and Boynton* with a steel of 0.55 per cent. carbon found that by cooling in the furnace from 1100° C. the ductility was greater but the strength less than in the case of the sample cooled in air. The dark etching constituent in the former is true pearlite, in the latter it is dilute pearlite, which they call sorbite.

The following tables and curves were obtained in working

TABLE I.—Steel $\frac{7}{16}$ in. square; C. 0.50 per cent.; Mn. 0.98 per cent. Bars cooled in the air.

Maximum Temperature. Degrees Centigrade.	Elastic Limit. Pounds per sq. in.	Maximum Load. Pounds per sq. in.	Elongation in 8 inches. Per cent.	Reduction of Area. Per cent.	
660	72,500	102,900	15.6	55.7	
680	67,100	104,100	17.5	50.8	
700	62,500	101,250	17.6	53.1	
720	63,700	102,300	17.4	54.3	
735	65,600	108,400	17.4	52	Fig. 8 (x 120).
745	75,200	112,000	16.25	51.5	Fig. 9 (x 65).
765	74,600	112,600	16.5	42.8	
775	74,600	112,200	....	50.6	
820	73,600	115,150	15	48.4	Fig. 11 x (65).
845	73,100	117,100	15.6	46	
900	71,400	115,000	11.9	41	Fig. 13 (x 40).
965	69,700	114,800	13.6	42.7	
1030	67,000	110,300	14	38.4	Fig. 15 (x 40).
1085	66,400	108,800	12.1	39.3	
1150	66,100	109,950	8.1	34.4	Fig. 17 (x 40).
1210	64,900	108,400	11.25	32.2	
1270	66,900	112,800	8.1	12.7	Figs. 19 and 21 (x 40).
1340	65,400	113,900	5.5	7.6	
1390	60,700	98,200	3.4	5.4	Figs. 23 and 25 (x 40).
As rolled	70,550	113,400	13.9	46.4	Fig. 7 (x 120).
700	62,400	100,400	14.3	55.8	

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* *Trans. A. I. M. E.*, XXXIV, page 150.

with steel $\frac{7}{16}$ inch square, C. 0.50 per cent., Mn. 0.98 per cent. Ac_1 was found to be 710° C.; Ac_{2-3} 745 to 750° C. The bars were heated in an iron muffle set in a cylindrical gas forge, and reached their maximum temperature in between one and two hours, after which one bar was withdrawn and allowed to cool in the air, another allowed to cool slowly in the furnace.*

TABLE II.—Steel $\frac{7}{16}$ in. square; C. 0.50 per cent.; Mn. 0.98 per cent. Bars cooled in the furnace.

Maximum Temperature. Degrees Centigrade.	Elastic Limit. Pounds per sq. in.	Maximum Load. Pounds per sq. in.	Elongation in 8 inches. Per cent.	Reduction of Area. Per cent.	
660	68,800	104,400	15.6	51.1	
680	67,400	103,850	16.9	53.2	
700	65,800	99,900	17.2	44.75	
720	62,700	99,250	17.0	51.9	
735	62,100	101,600	18.9	49.8	
745	67,500	105,300	18.25	45.9	Fig. 10 (x 65).
765	67,500	105,150	17.4	43.6	
775	65,800	105.100	18.25	45.2	
820	64,450	106,050	18.5	40.5	Fig. 12 (x 65).
845	64,800	106,400	16.4	37.3	
900	62,900	104,050	15.75	39.6	Fig. 14 (x 40).
965	62,000	103,900	15.6	38.6	
1030	59,600	101,600	15.7	37.4	Fig. 16 (x 40).
1085	57,500	99,750	14.5	37.4	
1150	57,500	100,100	10	36.4	Fig. 18 (x 40).
1210	54,000	97,200	13.75	36.8	
1270	57,600	99,600	13.75	36.3	Figs. 20 and 22 (x 40).
1340	54,500	99,200	11.8	14.1	
1390	51,800	89,100	6.2	8.0	Figs. 24 and 26 (x 40).
As rolled	70,550	113,400	13.9	46.4	Fig. 7 (x 120).
700	63,500	99,200	15.6	53.6	

The bars cooled in air are described in Table I, in which the first column denotes the maximum temperature of heating. Two heats were made to 700° C., the first in one hour, the second in one hour and a half, the temperature reaching between 700 and 705° C.

The bars cooled in the furnace are described in Table II. The figures in the two tables have been plotted in the curves shown in Figs. 37 to 40 for steel No. 1.

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* *Journal Iron and Steel Institute*, II, 1903, p. 359.

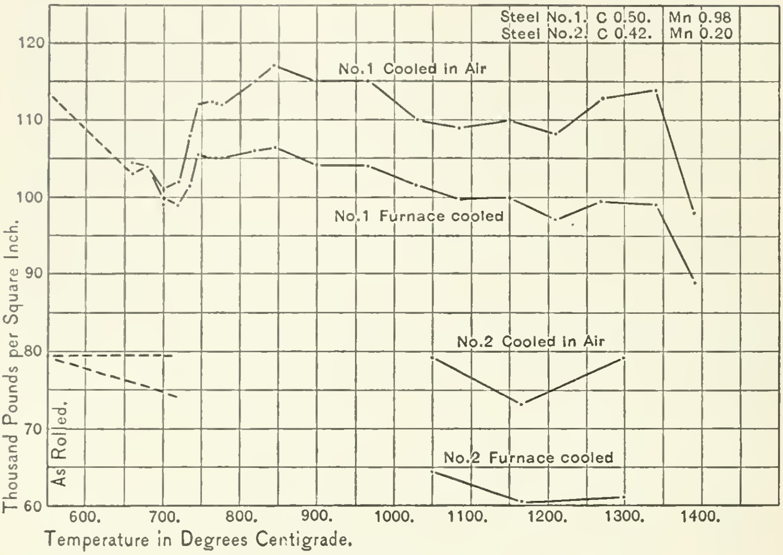
Steel No.1. C 0.50. Mn 0.98
Steel No.2. C 0.42. Mn 0.20
No.1 Cooled in Air
No.1 Furnace cooled
No.2 Cooled in Air
No.2 Furnace cooled
As Rolled.
Thousand Pounds per Square Inch.
120
110
100
90
80
70
60
600.
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
Temperature in Degrees Centigrade.

FIG. 37.

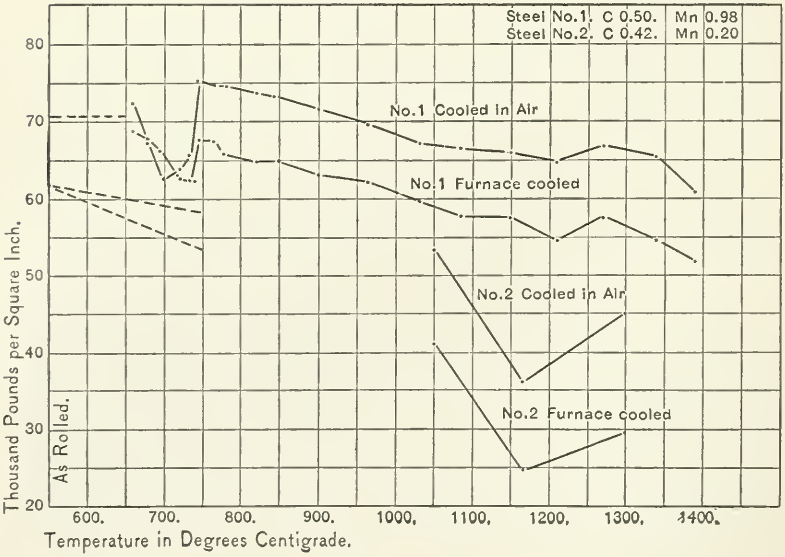
Steel No.1. C 0.50. Mn 0.98
Steel No.2. C 0.42. Mn 0.20
No.1 Cooled in Air
No.1 Furnace cooled
No.2 Cooled in Air
No.2 Furnace cooled
As Rolled.
Thousand Pounds per Square Inch.
80
70
60
50
40
30
20
600.
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
Temperature in Degrees Centigrade.

FIG. 38.

In Fig. 37 we have the two curves for the maximum loads which are roughly parallel, showing maxima at the 845° heat, etc. In Fig. 38 the elastic limits are shown with maxima at 745° C. and a fairly regular fall beyond that point.

In Fig 39 the elongations are plotted and while the curves are not very regular they are more or less parallel and show the furnace cooled specimens to be ahead of those cooled in the air. The maxima lie at 735° C.

In Fig. 40 the reductions of area are shown. Up to about 1100° C. the air-cooled bars show the greater reduction, and then fall off. The maxima occur about Ac_1, and up to 735° are equal to the original. Without going into the meanings of each of the curves individually we can sum up by saying that, after heating to temperatures above the critical point Ac_1, the strength of the bars cooled in air is greater than that of the bars cooled in the furnace. The ductility is less. On examining the microstructure and following the series of changes which occur, the reason is quite evident, being due to the presence of the greater amount of free ferrite in the furnace cooled bars.

The original steel as rolled is shown in Fig. 7 (x 120), and consists of irregular borders of ferrite round the darker pearlite grains. Heating to temperatures below Ac_1 has but little effect on grain size, but tends to change the texture of the pearlite. The finest grain is seen in Fig. 8 (x 120) heated to 735° C. and cooled in air whilst the best elastic limit is given by the 745° C. heat, cooled in air, shown in Fig. 9 (x 65). In contrast with this we have Fig. 10, the furnace cooled specimen, whilst the grain is the same the amount of ferrite has increased enormously. The series of changes are well shown in Figs. 7, 8, 9 and 10.

Above the critical point Ac_{2-3} the higher the temperature the coarser the grain, as will be seen in the following illustrations. The odd numbers show the air-cooled specimens, the even numbers those cooled in the furnace. Thus Fig. 11 (x 65) was heated to 820° and air-cooled; Fig. 12 (x 65) furnace-cooled; Fig. 13 (x 40) was heated to 900° and air cooled; Fig. 14 (x 40), furnace-cooled. Similarly Figs. 15 and 16 show the steel from the 1030° heat, Figs. 17 and 18 that from the 1150° heat, while Figs. 19 and 20 show the 1270° heat, from near the center of the specimen. The contrast in the relative amounts of ferrite is strong. The center of the

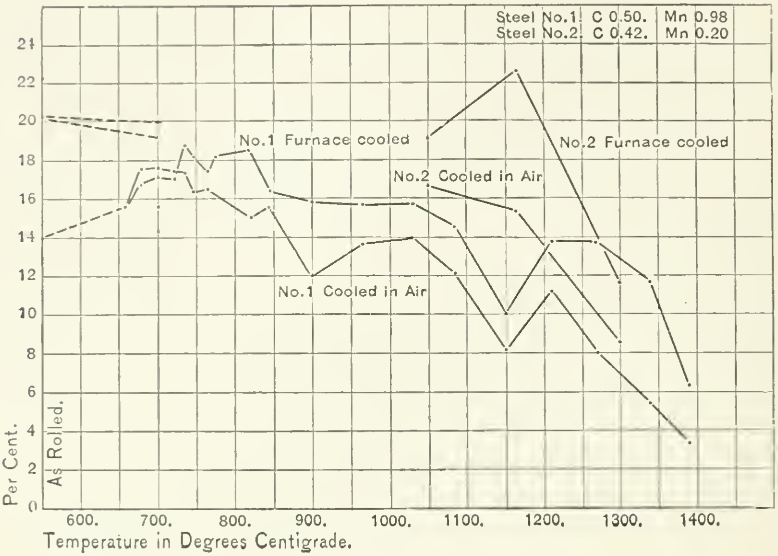
Steel No.1. C 0.50. Mn 0.98
Steel No.2. C 0.42. Mn 0.20
No.1 Furnace cooled
No.2 Furnace cooled
No.2 Cooled in Air
No.1 Cooled in Air
As Rolled.
Per Cent.
0
2
4
6
8
10
12
14
16
18
20
22
24
600.
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
Temperature in Degrees Centigrade.

FIG. 39.

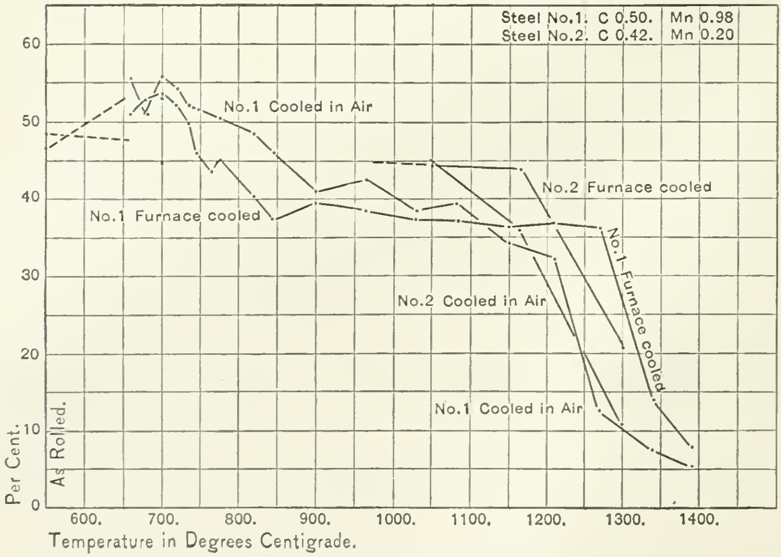
Steel No.1. C 0.50. Mn 0.98
Steel No.2. C 0.42. Mn 0.20
No.1 Cooled in Air
No.2 Furnace cooled
No.1 Furnace cooled
No.1 Furnace cooled
No.2 Cooled in Air
No.1 Cooled in Air
As Rolled.
Per Cent.
0
10
20
30
40
50
60
600.
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
Temperature in Degrees Centigrade.

FIG. 40.

largest grain in Fig. 19 shows a curious structure which is also seen in Fig. 23. Under a high power it has the appearance of martensite (or quenched steel) and is evidently due to incomplete change of the solid solution caused by the comparatively rapid rate of cooling. On the outsides of these bars there was a certain amount of decarburization. That of the air-cooled specimen is shown in Fig. 21, while that of the furnace-cooled one is seen in Fig. 22. In Fig. 21 there is a curious network of ferrite within the coarsest of the pearlite grains, but in Fig. 22 there is a sharp division between the ferrite and the pearlite. Figs. 23 and 24 show the specimens heated to 1390°, whilst Figs. 25 and 26 show the same near the outside where decarburization has taken place. In Fig. 25 the separation of the ferrite as a network within the very coarse grain of pearlite is even more marked.

To sum up the changes, then, as shown in Figs. 7 to 26, we have the refining of the grain at 735° C. followed by a more abundant and distinct separation of the ferrite in the 745° heat and above, when slowly cooled, the higher the temperature the coarser the grain.

A third set of bars were withdrawn from the furnace, along with those to be cooled in air, and cooled in lime. Their physical properties and microstructure lie intermediate between those of the air cooled and furnace cooled bars. This is what we should expect, for cooling in lime would be more rapid than furnace cooling but considerably slower than cooling in the open air.

A second steel $\frac{7}{16}$ inch square, 0.42 per cent. C., Mn 0.2 per cent. gave similar results. The figures given in Table III were obtained by F. Lage* in working on this material under my direction. They have been plotted in the curves in Figs. 37 to 40 as steel No. 2. They also show that the furnace-cooled bars have less strength but greater ductility than those cooled in air.

An examination of the microstructure shows the same excess of ferrite in the furnace-cooled specimens as before. The material as rolled is shown in Figs. 27 and 28, a cross section and a longitudinal section respectively (x 50 dias.) Fig. 29 (x 45) shows the steel after heating to 1050° C. and cooling in air, while Fig. 30

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* Thesis for the Degree of Metallurgical Engineer, Columbia University, 1907.

TABLE III.—Steel $\frac{7}{16}$ in. square; C. 0.42 per cent.; Mn. 0.2 per cent.

Maximum Temperature. Degrees Centigrade.	Bars cooled in Air.					Bars cooled in Furnace.				
	Elastic Limit. Pounds per sq. in.	Maximum Load. Pounds per sq. in.	Elongation in 8 inches. Per cent.	Reduction of Area. Per cent.		Elastic Limit. Pounds per sq. in.	Maximum Load. Pounds per sq. in.	Elongation in 8 inches. Per cent.	Reduction of Area. Per cent.	
As rolled	61.500	79,300	21.1	47.5	Figs. 27 and 28 (x 50).					
	62,000	79,250	20.6	49.7						
1050	57,200	80,200	17	43.8	Fig. 29 (x 45)	41,800	64,420	19.4	44.5	Fig. 30 (x 45).
	49,600	78,530	16.4	44.9		40,900	64,500	18.8	43.4	
1165	37,500	73,710	15.0	35.4	Fig. 31 (x 45)	21,930	61.250	21.1	42.8	Fig. 32 (x 45).
	36.560	72,600	15.6	36.4		27,760	60,000	24.1	44.9	
1300	45,800	79,870	8.8	10.5	Figs. 33 and 35 (x 45)	29,130	61,200	11.6	20.75	Figs. 34 and 36 (x 45).
	45,040	78,880	8.5	11.0		30,000	61,150	....	.....	

shows the same after cooling in the furnace. Similarly Figs. 31 and 32 show the 1165° heat cooled in air and in the furnace, whilst Figs. 33 and 34 show the same for the 1300° heat. In all, the increase in ferrite in the furnace cooled specimens is marked. The difference in the structure of the decarburized outer layer is seen in Figs. 35 and 36, the specimens heated to 1300° C., the much coarser segregation of the ferrite in Fig. 36 being pronounced.

CONCLUSIONS.

The above illustrations confirm the work of others and point to the following general conclusions:

1. To refine steel of 0.40 to 0.50 per cent. carbon, heat to Ac_{2-3} or about 750° C. If the material is already comparatively fine grained a slightly lower temperature is required; if coarse grained, such as cast or overheated steel, then a slightly higher temperature is needed. Again, the lower the carbon and manganese the higher the temperature. We can put the limits therefore between 735° and 785° C.

2. After heating to temperatures above Ac_1 (say 710° C.) by cooling in air as contrasted with slow cooling in the furnace, we gain in strength at the expense of the ductility.

3. This slow cooling produces a more complete separation of the excess ferrite and a more defined or segregated eutectoid, pearlite.

4. Rapid cooling conversely tends to prevent the complete separation of the excess ferrite and yields the eutectoid in the "sorbitic" or unsegregated conditions.

In conclusion the thanks of the author are due to the Carnegie Institution of Washington for a grant for apparatus to carry on research along this line of investigation.

PHOTOMICROGRAPHS.

Fig. 1. Ingot of 0.45 per cent. carbon as cast, shows very coarse structure. Light ferrite in dark etching pearlite (x 45).

Fig. 2. The same after reheating to just above the lower critical point. The structure now is extremely fine and shows more abundant ferrite, the lighter constituent (x 45).

Fig. 3. Underside of rail head as rolled C. = 0.38 Mn. 0.80 per cent. (x 45).

Fig. 4. The same after reheating, a great increase in the light constituent, ferrite (x 45).

Fig. 5. Center of rail head as rolled C. = 0.40 Mn. 0.80 per cent. Medium grains of dark pearlite with a network of lighter ferrite (x 45).

Fig. 6. The same after reheating, grain now extremely fine and ferrite much more abundant (x 45).

Steel No. 1. C. 0.50. Mn. 0.98 per cent.

Fig. 7. As rolled. Dark grains of pearlite, with irregular borders of lighter ferrite (x 120).

Fig. 8. Heated to 735° C. and cooled in air, grain has been refined. Shows the best ductility (x 120).

Fig. 9. Heated to 745° C. and cooled in air, grain coarser. Shows the best elastic limit (x 65).

Fig. 10. The same, furnace cooled, much more ferrite than in Fig. 9 (x 65).

Fig. 11. Heated to 820° C. and cooled in air, grain coarser than in Fig. 9, coarser than in Fig. 7 the original steel and much more clearly defined (x 65).

Fig. 12. The same, furnace cooled. Ferrite much stronger (x 65).

Fig. 13. Heated to 900° C. and cooled in air (x 40).

Fig. 14. The same, furnace cooled. Much more ferrite than in Fig. 13 (x 40).

Fig. 15. Heated to 1030° C. and cooled in air (x 40).

Fig. 16. The same, furnace cooled (x 40).

Fig. 17. Heated to 1150° C. and cooled in air (x 40).

Fig. 18. The same, furnace cooled (x 40).

Fig. 19. Heated to 1270° C. and air cooled (x 40).

Fig. 20. The same, furnace cooled, all show a progressive coarsening of the grain and the increased ferrite in the furnace-cooled sample.

Fig. 21. Shows the outside of the specimen heated to 1270° C., air cooled, grain very coarse (x 40).

Fig. 22. The same, furnace cooled. The difference between these two is characteristic (x 40).

Figs. 23 and 25. Heated to 1390° C. and cooled in air, the latter from the outside to show the decarburization (x 40).

Figs. 24 and 26. The same, furnace-cooled, further accentuate the differences between the two specimens (x 40).

Steel No. 2. C. 0.42. Mn. 0.20 per cent.

Fig. 27. The steel as rolled. Cross section, shows a fine-grained mixture of ferrite and pearlite (x 50).

Fig. 28. The same. Longitudinal section, grains slightly drawn out in the direction of rolling (x 50).

Fig. 29. Heated to 1050° C. and cooled in air (x 45).

Fig. 30. The same, cooled in furnace (x 45).

Fig. 31. Heated to 1165° C. and cooled in air (x 45).

Fig. 32. The same, furnace cooled (x 45).

Fig. 33. Heated to 1300° C. and cooled in air (x 45).

Fig. 34. The same furnace cooled; all show a progressive coarsening of the grain, with the greatly increased ferrite in the slowly cooled samples.

Fig. 35. Shows the decarburized outer layer of the sample heated to 1300° C. and air cooled. A mat-like mass of ferrite grading into pearlite very sharply (x 45).

Fig. 36. Shows the same, furnace cooled. A more gradual increase in pearlite in depth, a sharper separation of ferrite and pearlite, etc. Shows marked difference between the two rates of cooling (x 45).

NOTES ON THE ENDURANCE OF STEELS UNDER REPEATED ALTERNATE STRESSES.

By James E. Howard.

Three diagrams are presented on the behavior of steels under repeated alternate stresses, illustrating some of the tests which have been made at the Watertown Arsenal laboratory. Fig. 1 shows the arrangement of the apparatus.

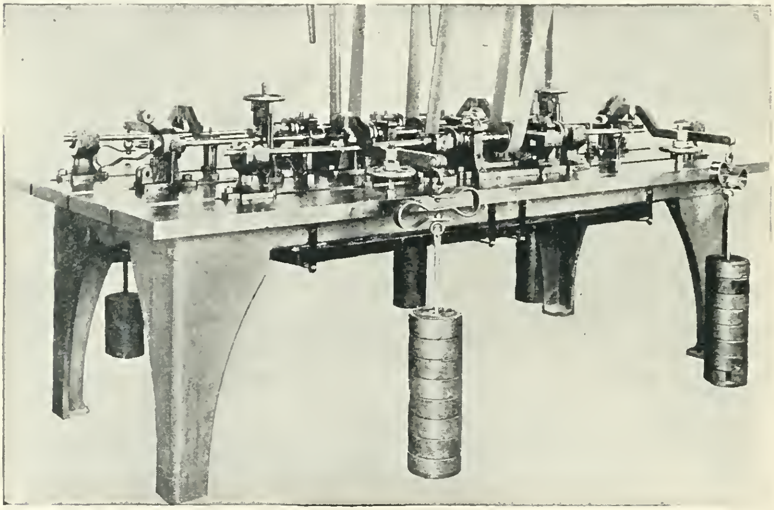

Fig. 1.

On Diagram I the heavy vertical lines represent the number of loads which were applied to a number of steel bars, of .55 per cent. carbon, and which caused rupture of the metal. Beginning with the highest fiber stress, 60,000 pounds per sq. in. the progressive gain in endurance of the steel as the loads were successively reduced will be noted, as indicated by the lengths of the different lines. The lowest fiber stress experimented with did not end in rupture of the shaft; after 76 million repetitions, in round numbers, under a load of 30,000 pounds per sq. in., the fiber stress was increased to 60,000 pounds per sq. in., which higher load caused rupture after about 8,000 rotations. The enormous gain in endurance of the steel, under 30,000 pounds

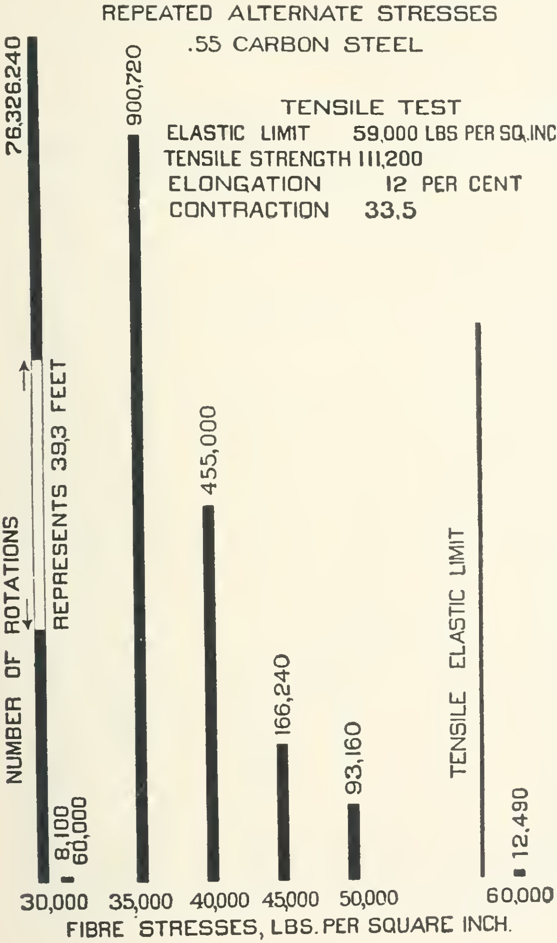

Diagram I.

fiber stress, over its behavior with the higher loads, would be represented by a vertical line about one-twelfth of a mile in height, according to the scale of this diagram. The results of the tensile tests of this grade of steel are entered on the diagram, from which it may be seen that the several fiber stresses were, with one exception, below the tensile elastic limit of the metal.

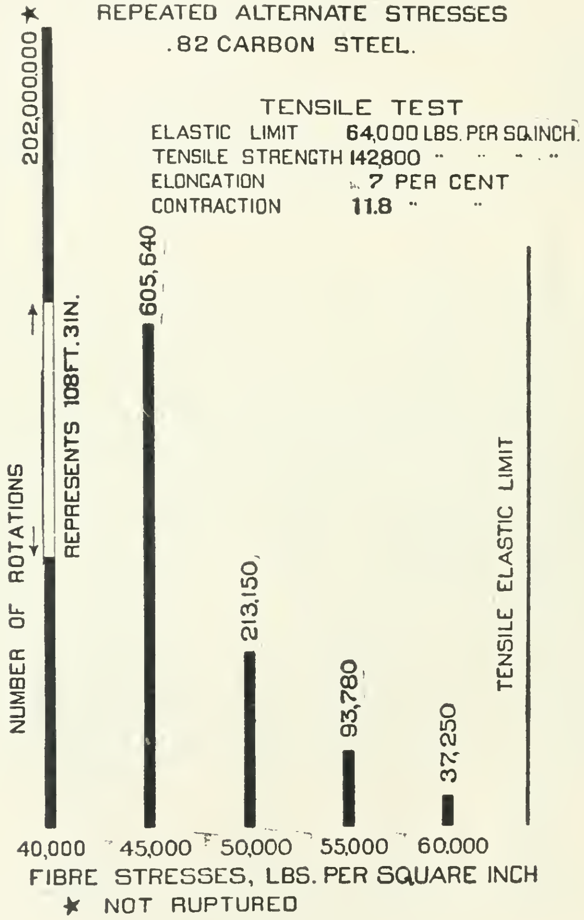

DIAGRAM II.

On Diagram II similar lines represent the behavior of specimens containing .82 per cent. carbon. The behavior of this grade resembles that of the previous diagram, and similar to other steels belonging to this series of experiments. The endurance under corresponding loads is seen to be greater than displayed on the preceding diagram. After making 202 million rotations the test

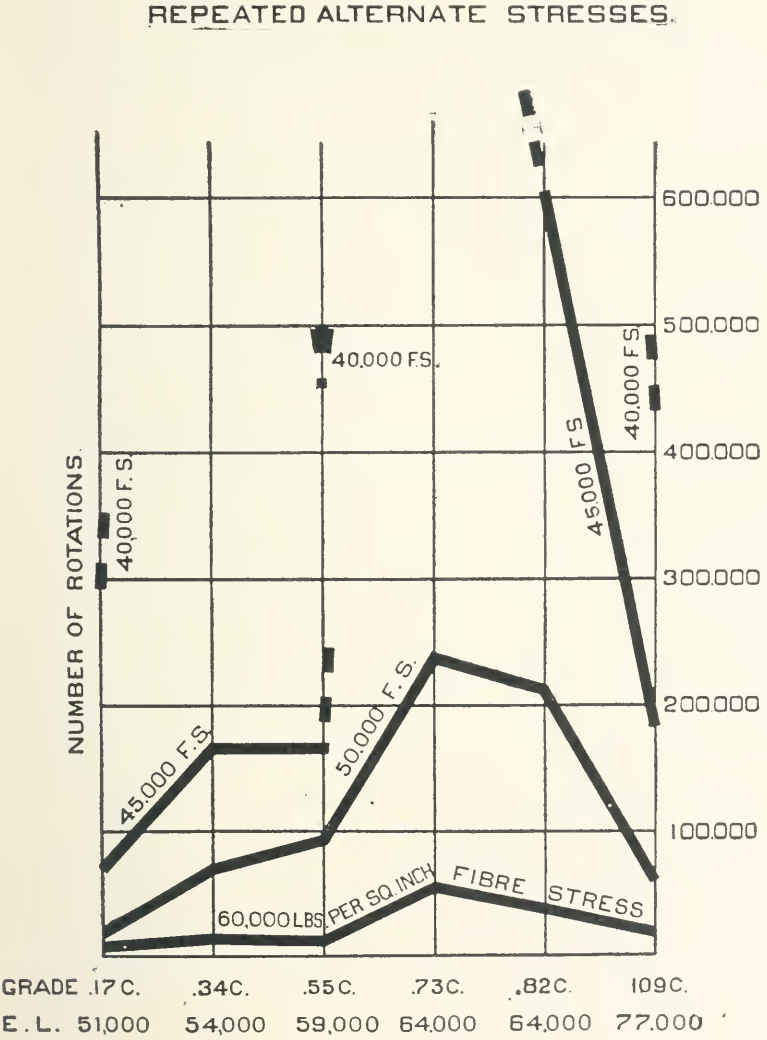

DIAGRAM III.

of the shaft loaded with 40,000 pounds has been temporarily discontinued, the steel being unruptured. A line drawn to scale representing the endurance under this load would be about one-fifth of a mile in height.

On Diagram III appear curves representing the relative endurance of each of the six grades of steel used in this series of experiments. Their endurance under the higher fiber stresses only are shown, loads which caused comparatively early rupture of the steel in most of the tests.

It may be remarked that the fiber stresses experimented with were generally below the tensile elastic limits of the steels. The greater endurance of the steels of .73 and .82 per cent. carbon in comparison with either the higher or the lower carbons is an interesting feature of the tests.

Elastic properties only are displayed by steels, prior to rupture, when rupture is caused by a large number of alternate stresses of tension and compression. No appreciable display of ductility, as shown by elongation and contraction of area, need precede rupture, in any grade of steel, following the application of stresses of this kind. If the fiber stresses somewhat exceed the tensile elastic limit a limited display of elongation, other than elastic, may occur, but rupture caused by loads which are in the vicinity of or below the tensile elastic limit is not attended with an appreciable display of ductility. There is a certain limit, experimentally ascertainable, and except in a general way it would seem not otherwise, above which a comparatively small number of repetitions will cause rupture, while under lower loads the limit of endurance is greatly prolonged. The relation of this divisional line to the properties displayed in the tensile test, present information is thought to be inadequate to define..

It has been found that steels ruptured by repeated stresses while at a blue heat endure a geater number of loads than when ruptured at ordinary atmospheric temperatures. In this connection it will be recalled that the tensile strength of steel is greater at 400 to 600 degrees F. than when at 70 degrees. Some examples have been found in which steels after having endured a large number of stresses and then tested by direct tension have displayed higher strength than normal to the metal. These results have suggested the probable influence of ultimate strength on the question of endurance in conjunction with the range of elastic movement which steels may be subjected to.

Efforts made to prolong the limit of endurance by occasionally annealing the metal have not been successful. Further efforts, however, will be made in that direction since it is a matter of much interest to acquire information concerning the manner in which rupture is approached and accomplished by loads so much inferior to those which are required when once applied.

While tests by repeated alternate stresses are characterized by the absence of ductility as witnessed in tests by tension there may be elastic movements of the metal aggregating considerable distances. The aggregate extension of the most strained fiber of the .82 per cent. carbon steel which has successfully endured 202 million repetitions amounts to nearly five miles per linear inch of specimen, a distance quite incomparable to the permanent extension of the metal in the tensile test. Occasional eccentric fractures, in some steel occasioned by local defects, emphasize the importance of structural soundness in the metal, the tensile properties themselves of a given grade of steel being under considerable control by methods of working.

EFFECT OF COMBINED STRESSES ON THE ELASTIC PROPERTIES OF STEEL.

By E. L. Hancock.

During the past year tests have been continued under the direction of the writer to determine the effect of combined stresses on the elastic properties of steel. These tests form a part of the general plan for such tests carried on in the Laboratory for Testing Materials of Purdue University (Vol. V, page 179, and Vol. VI, page 295). The tests already made and reported to this Society have included tests in tension and compression while the material was under torsion. The tests reported in this paper were made by first subjecting the material to tension or compression and then, while under such stress, applying certain increments of torsion. In the tension-torsion tests, tensile stresses of 0, 33, 50, 69, 81 and 100 per cent. of the normal elastic limit in tension were first applied, and while the material was under such tension it was tested in torsion. In the compression-torsion tests, compressive stresses of 0, 33, 50, 83 and 100 per cent. of the normal elastic limit in compression were applied and while the material was under such stress it was tested in torsion. A third series of tests were made on full-sized steel shafting, by first subjecting the material to a certain torque, and then, while under such torque, testing it in flexure.

The writer hopes, at an early date, to be able to make a general review of all tests made, and to accompany it with a proper analysis of all data thus far obtained. In the meantime, the tests themselves are reported.

MATERIALS.

The material used in the tension-torsion and the compression-torsion tests was a grade of steel tubing furnished by the Shelby Steel Tube Company. The tension-torsion test pieces were 32 inches long, 1 inch outside diameter and $\frac{29}{32}$ inches inside diameter. The compression-torsion test pieces were 8 inches long and of the same size and thickness as the tension-torsion test pieces. Simple tension tests showed the material to have the following physical properties: Maximum strength, 41,000 pounds per square inch, elastic limit, 21,000 pounds per square inch and per cent. of elongation in 8 inches of 32. It was thoroughly annealed and of uniform thickness. The material used in the torsion-flexure tests consisted of solid nickel and mild carbon steel shafting furnished by the Carnegie Steel Company. The nickel steel was of the same chemical composition as the carbon steel, except that it had about 3 per cent. of nickel. The pieces of shafting tested were 5 feet

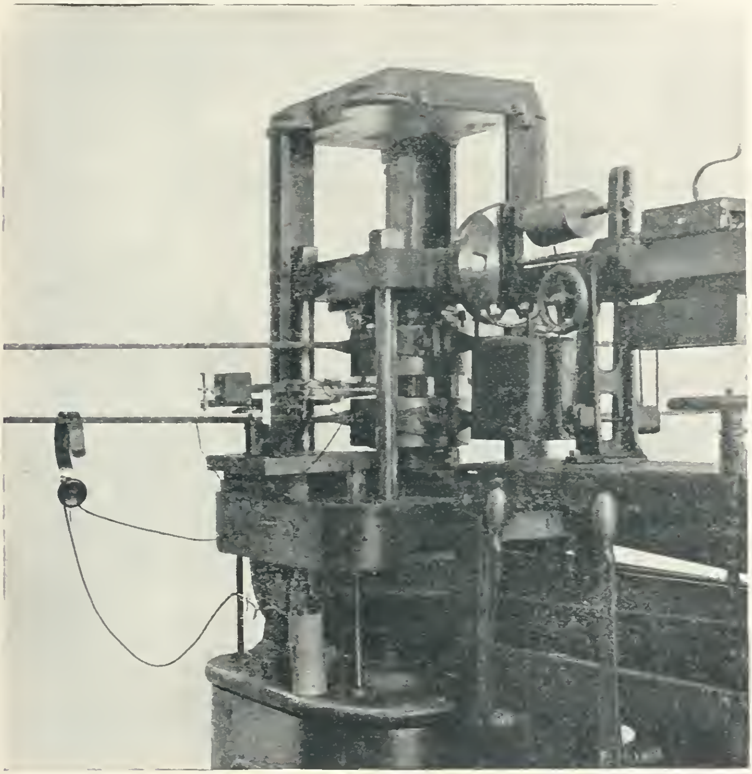

FIG. 1.

long and turned down to $1\frac{1}{2}$ inches in diameter. These pieces were squared slightly at the ends to provide for the application of the torque.

METHOD OF TEST.

The method of testing pieces in tension while already under torsion has been explained (see Vol. V, p. 179). The same apparatus and arrangement of apparatus was made use of in testing in torsion while under tension. After the desired tensional load was applied, sufficient torsional load was put on, to overcome the friction of the ball-bearing heads, and then the piece was tested in torsion. Elongations were measured with a Johnson exten-

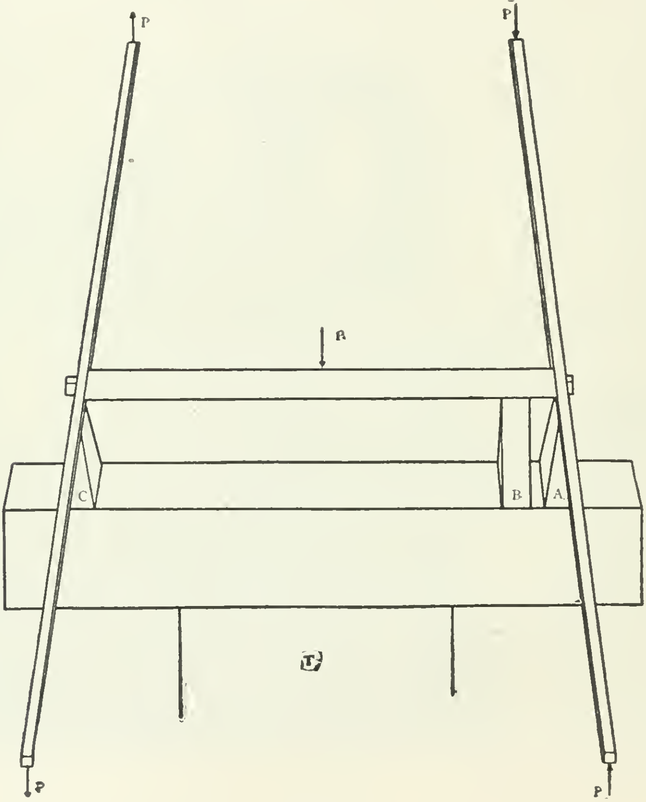

FIG. 2.

someter and torsional deformations by means of an Olsen troptometer. Deformations in both tension and torsion were measured on an 8-inch gauge length. To determine the torque necessary to overcome the friction of the ball-bearing heads, due to the tensional load, the troptometer was set at zero and sufficient sand added to

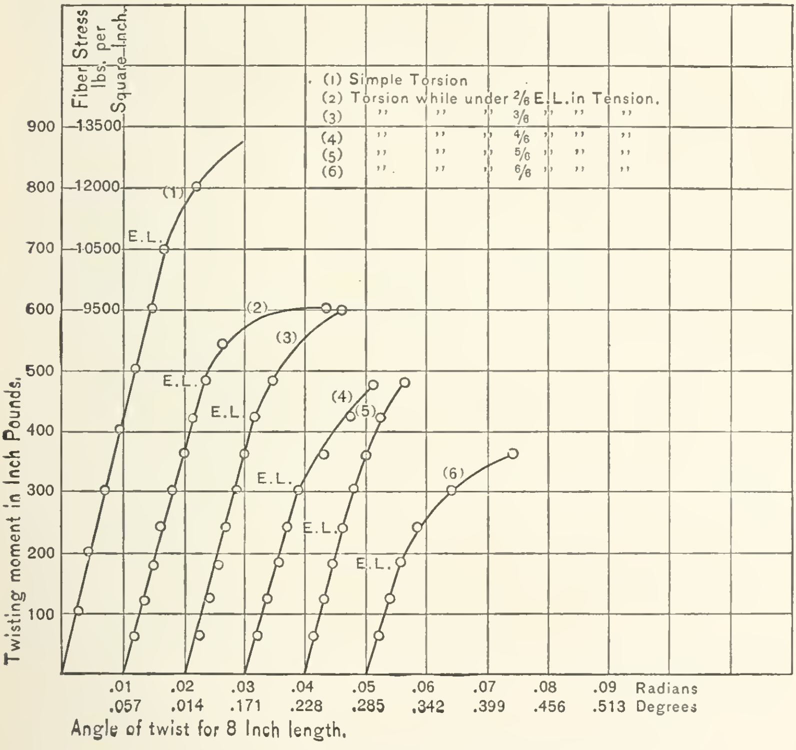

FIG. 3.—Steel Tubing in Tension-Torsion.

the pails at the ends of the arms to cause a perceptible motion. This method proved accurate and satisfactory .

In making the compression-torsion tests, the upper ball-bearing head was placed upon the platform of the testing machine with the same side up as when it was on top of the machine. The other ball-bearing head was left on the under side of the moving head of the testing machine. In this position the compression specimen was inserted and the same set of jaws that applied tension and torsion in the tests just described, applied compression when the moving head of the machine was lowered, and afterward applied torsion. The compression specimens were 8 inches long, and this length, after allowing 2.5 inches on each end for insertion in the jaws, gave a compression length of three inches. Compression and torsion were both measured on a 2-inch gauge length. Deformations were measured with an Olsen compressometer and

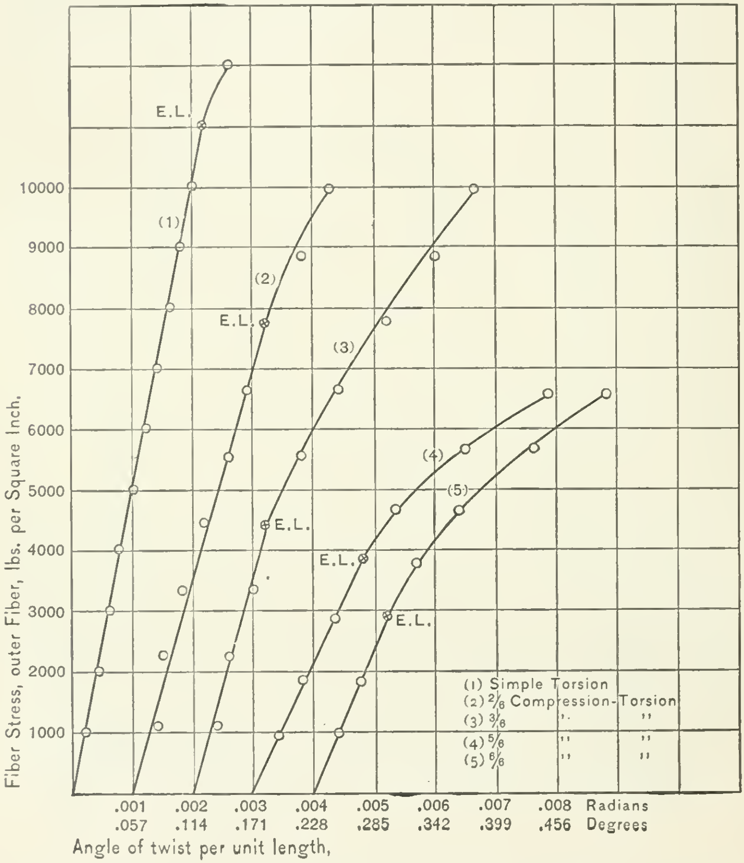

FIG. 4.—Steel Tubing in Compression-Torsion.

troptometer. The disposition of the specimen in the machine and the arrangement of the compressometer are shown in Fig. 1, although this is not a photograph of one of the test pieces and the troptometer is not shown. Torsion loads were obtained by adding the required amount of sand to the pails, attached to the ends of the arms, in a manner similar to that used in the tension-torsion tests. After the required compressional load was applied, sufficient sand was placed in the pails to overcome the friction of the ball-bearing heads. This was indicated by a perceptible movement of the troptometer index. In making these compression-torsion tests, great care was used to avoid any possible column action of the specimen. It is believed by the writer that no such action took place in the case of any tests reported in this paper.

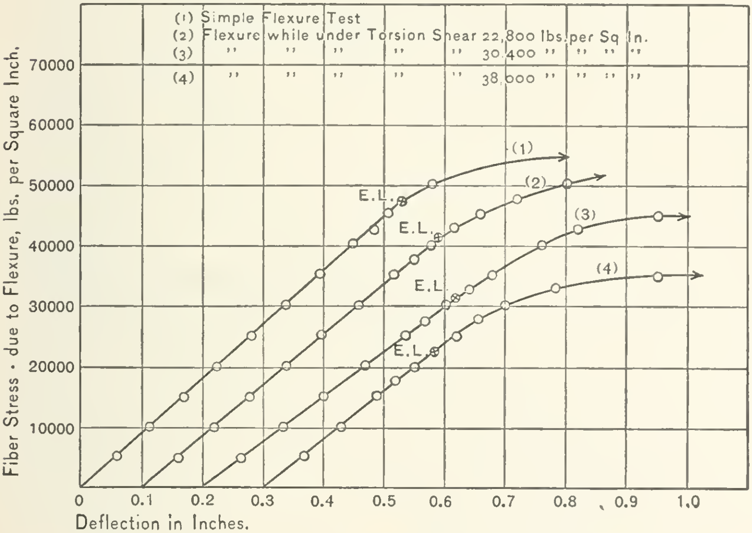

FIG. 5.—Carbon Steel Shafting in Torsion-Flexure.

The torsion-flexure tests of nickel and carbon steel shafting were made by means of specially devised apparatus. The same arms used in the preceding tests were attached to the ends of the specimen. The attachment of these arms and the general disposition of the specimen with relation to the testing machine is shown schematically in Fig. 2. The testing machine, upon which the apparatus was mounted and which was used in the flexure part of test, was an ordinary tension machine of 20,000 pounds capacity. T is the platform of the testing machine. The torque was applied by means of weights, indicated in the drawing by the arrows P. The plan throughout was, first, the application of a certain torque, and then while the shaft was under this torque subjecting it to a flexure test. While the torque was being applied the knife-edge A was removed, allowing the shaft to turn freely over the knife-edge B. When the desired torque had been applied the knife-edge B was removed and the knife-edge A inserted. The downward force P at the end of the shaft, indicated by A, was obtained by allowing the desired weight to hang from the end of the arm. The upward force P, at the same end A, was obtained by allowing the desired weight to hang from a bicycle chain which ran over a suitably mounted bicycle wheel

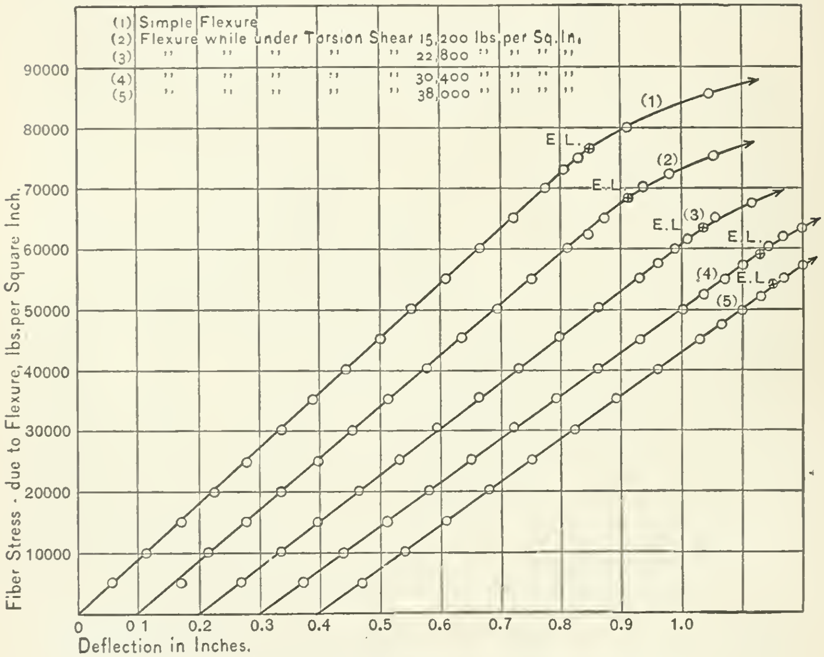

FIG. 6.—Nickel Steel Shafting in Torsion-Flexure.

and fastened to the other end of the arm, in such a way as to give the required vertical upward pull. The friction of the wheel and chain were negligible. The arm at the end C was the fixed arm. The specimens were tested in flexure by applying the load P at the center by means of the testing machine. Torsional deformations were measured on a gauge length of 4 feet 9 inches by means of an Olsen troptometer. Flexural deformations were measured with an Olsen deflectometer. After the torque had been applied the beam of the testing machine was balanced, eliminating from consideration the weight of the cross beam and the weights used in applying the torsion.

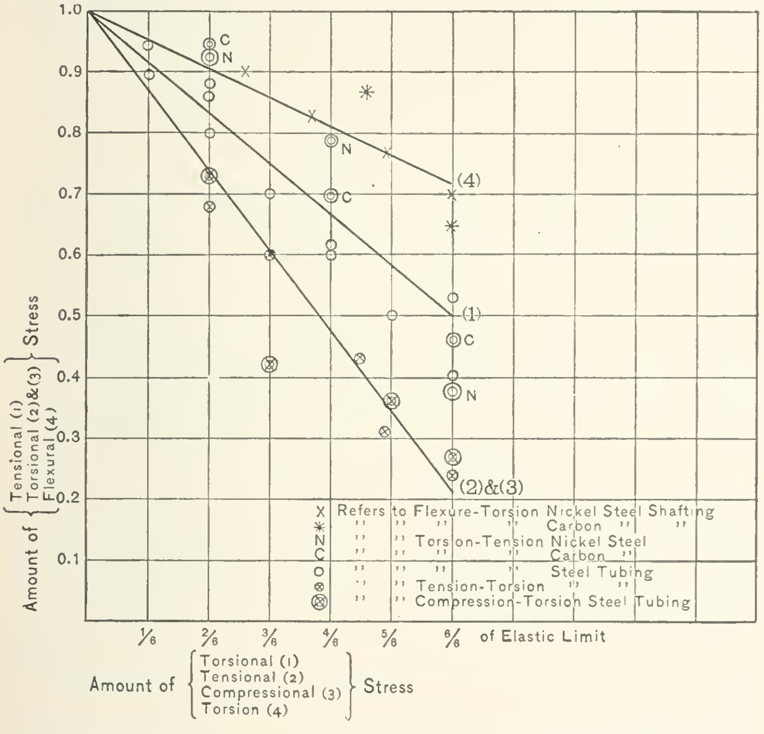

FIG. 7.—Curves showing Lowering of Elastic Limit of Steel due to Combined Stresses.

RESULTS.

The lowering of the torsional elastic limit of steel tubing due to the various tensional loads is shown by Fig. 3. Curve 1 shows the results of simple torsion tests, curve 2 the results of torsion tests while the material was under tension to $\frac{2}{6}$ the elastic limit in tension. Curves 3, 4, 5 and 6 show the results of torsion tests while the material was under tension of $\frac{3}{6}$, $\frac{4}{6}$, $\frac{5}{6}$ and $\frac{6}{6}$, respectively, the elastic limit in tension. Each curve represents, at least, an average of two tests.

TABLE I.

RESULTS OF TESTS OF STEEL TUBING; TENSION-TORSION AND COMPRESSION-TORSION.

Tension stress, lbs. per sq. inch. applied.	Per cent. of elastic limit in tension.	Elastic limit in torsion obtained.	Per cent. of elastic limit in torsion.	Angular deformation at elastic limit per unit length.	Per cent. of normal deformation.	Modulus of elasticity of shear, lbs. per sq.	Per cent. of normal modulus of elasticity.
0	0	10,500	100	.0021	100	10,350,000	100
7,000	33	7,200	68	.0017	82	9,075,000	87
10,500	50	6,300	60	.0013	64	10,350,000	100
14,000	69	4,500	43	.0011	53	9,075,000	87
17,000	81	3,300	31	.0007	35	9,680,000	93
21,000	100	2,700	25	.0007	35	8,066,000	77

COMPRESSION-TORSION TESTS.

0	0	10,500	100	.0021	100	10,000,000	100
8,000	33	7,700	73	.0022	104	7,000,000	70
12,000	50	4,500	42	.0012	57	7,500,000	75
20,000	83	3.800	36	.0018	85	4,200,000	42
24,000	100	2,900	27	.0012	57	5,000,000	50

The results of the compression torsion tests are shown by Fig. 4. Curve 1 shows the results of simple torsion tests of the material. Curve 2 shows the result of torsion tests while the material was under a compression of $\frac{2}{6}$ the elastic limit in compression. Curves 3, 4, and 5 show the results of torsion tests while the material was under compression to $\frac{3}{6}$, $\frac{5}{6}$ and $\frac{6}{6}$, respectively, the elastic limit in compression. Each curve represents an average of two or more tests. The values of $\frac{2}{6}$, $\frac{3}{6}$, etc., of the elastic limit was not in every case exactly noted but the results used in the tables and curves show a discrepancy in only one or two cases.

The results of the torsion-flexure tests of nickel and carbon steel are shown by Figs. 5 and 6. Fig. 5 shows the results of the tests of mild carbon steel shafting. Curve 1 shows the result of a flexure test of a piece of the shafting when no torsion is applied.

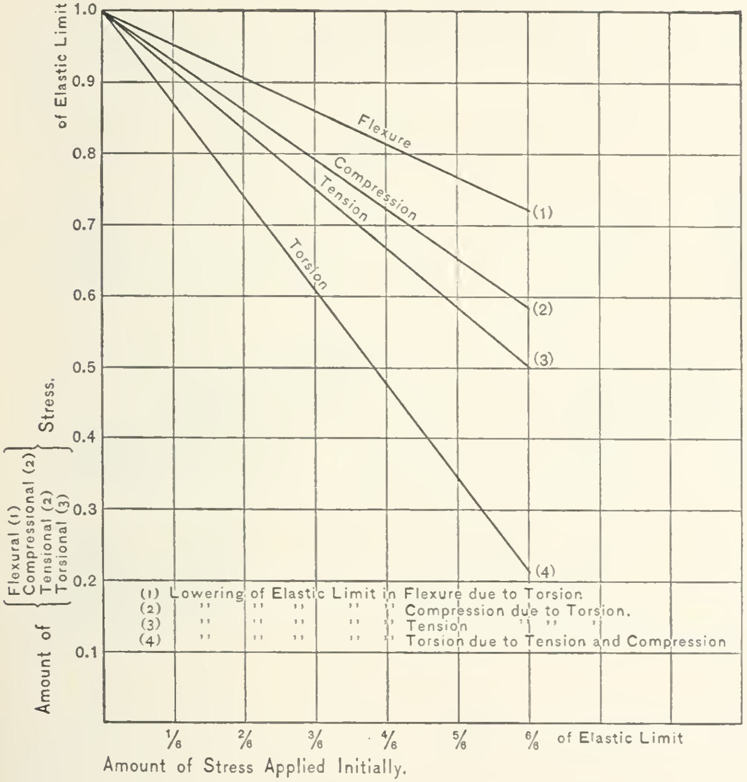

FIG. 8.—Curves showing the Lowering of the Elastic Limit of Steel in Tension, Torsion, Flexure and Compression, due to Combined Stresses.

Curve 2 shows the results of a flexure test of a similar piece of shafting while it was under a fiber stress of 22,800 pounds per square inch on the outer fiber. Curves 3 and 4 show the results of flexure tests of shafting while under a stress on the outer fiber, due to torsion, of 30,400 and 38,000 pounds per square inch, respectively, Fig. 6 shows the results of test of nickel steel shafting. These pieces of shafting were the same size as those of carbon steel.

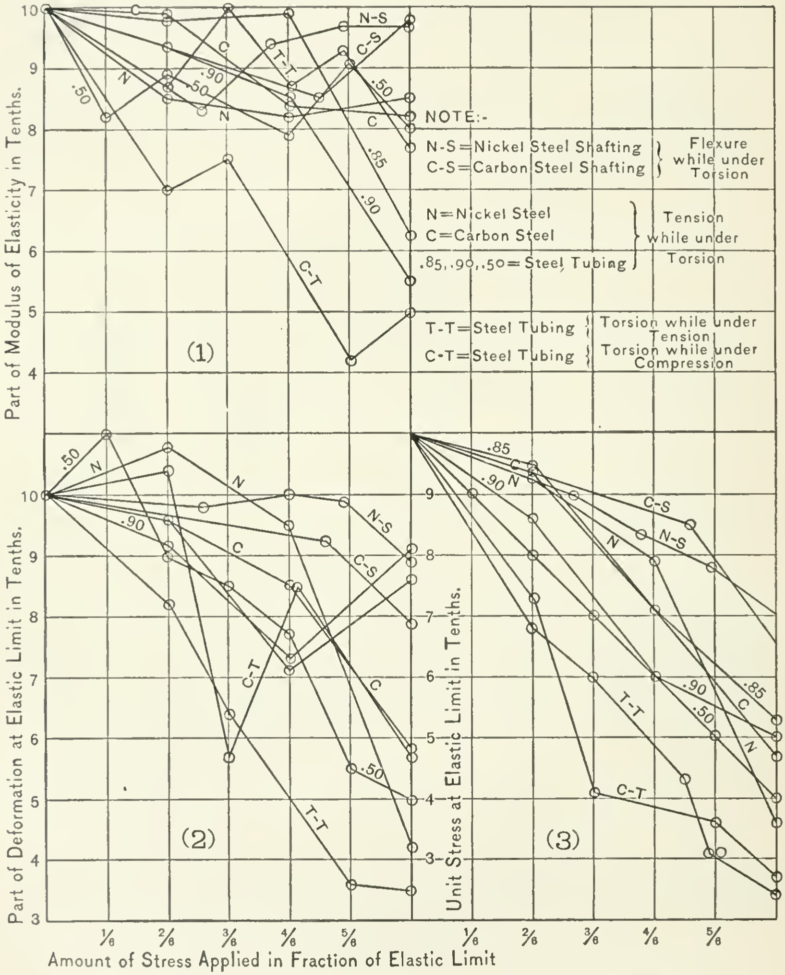

FIG. 9.—Curves showing the Effect of Combined Stresses on
(1) Modulus of Elasticity.
(2) Deformation at Elastic Limit.
(3) Unit Fiber Stress at Elastic Limit.

Curve 1 shows the result of a simple flexure test. Curves 2, 3, 4 and 5 show the results of flexure tests while the material was under a torque sufficient to produce a fiber stress in the outer fiber of 15,200, 22,800, 30,400, and 38,000 pounds per square inch, respectively.

The change in the elastic limit in tension, torsion and flexure due to the presence of another stress, torsion, tension, compression, and torsion, is shown in Fig. 7. The abscissæ represent the amount of the particular stress initially applied and the ordinates the portion of the elastic limit (normal elastic limit) obtained in tension, torsion and flexure as a result of the initial stress. All the results that have been obtained by the writer are shown in the diagram, so that, not only are the tests made during the past year represented, but also all those that have been reported heretofore. These points are averaged by lines 1, 2, 3 and 4 in Fig. 8. The figure needs no explanation.

TABLE II.

RESULTS OF TESTS ON MILD CARBON AND NICKEL STEEL SHAFTINGS IN FLEXURE WHILE UNDER TORSION.

Specimen.	Shear applied, lbs. per sq. in.	Elastic limit in flexure, lbs. per sq. in.	Per cent. of normal elastic limit.	Modulus of elasticity in flexure, lbs. per sq. in.	Per cent. of normal modulus of elasticity.	Deflection at elastic limit in inches.	Per cent. of normal deflection.	Per cent. of torsional elastic limit applied.
Mild Carbon Steel.								
1	0	47,000	100	32,900,000	100	.530	100	0
2	22,800	41,000	87	28,400,000	86	.490	92	75
3	30,400	31,000	67	32,400,000	98	.420	79	100
4	38,000	22,500	48	31,500,000	95	.280	53	125
Nickel Steel.								
1	0	76,500	100	33,300,000	100	.840	100	0
2	15,200	69,000	90	27,700,000	83	.820	98	40
3	22,800	64,000	83	31,500,000	94	.840	100	60
4	30,400	59,000	77	32,300,000	97	.830	99	80
5	38,000	54,000	70	32,300,000	97	.75	89	100

The change in the unit stress at the elastic limit, part of deformation at elastic limit and the modulus of elasticity is shown by Fig. 9. The amount of stress applied initially is represented on the horizontal axis and the corresponding change produced by this initial stress is shown on the vertical axis. It is seen that the unit stress at the elastic limit, deformation and modulus of elasticity are all lowered by the stress initially applied.

The results obtained from the tests of steel tubing, in torsion while under tension are shown in Table I. The table shows that an amount of tension applied, equal to 0, 33, 50, 69, 81 and 100 per cent. of the elastic limit in tension, produces an elastic limit in torsion of 100, 68, 60, 43, 31 and 25 per cent. of the normal elastic limit in torsion, respectively. The same table also gives the results of the compression-torison tests, showing that an amount of compression applied, equal to 0, 33, 50, 83 and 100 per cent. of the normal elastic limit in compression produces an elastic limit in torsion of 100, 73, 42, 36 and 27 per cent. of the normal elastic limit in torsion, respectively. It is seen from this table, as well as from Fig. 9, that the unit stress and unit strain at the elastic limit are lowered considerably, due to the combined stresses, and that the modulus of elasticity is also lowered, but to less degree. That is, the strength of the material suffers most when combined stresses are acting.

TABLE III.

RELATION BETWEEN THE BENDING MOMENT IN TORSION AND THE BENDING MOMENT IN FLEXURE IN THE TORSION-FLEXURE TESTS OF STEEL SHAFTING.

	Carbon Steel.		Nickel Steel.	
Specimen.	Torsional moment applied in inch lbs.	Bending moment in flexure in inch lbs.	Torsional moment applied in inch lbs.	Bending moment in flexure in inch lbs.
1	0	15,150	0	24,170
2	14,400	12,950	9,600	21,800
3	19,200	9,800	14,400	20,200
4	24,000	7,100	19,200	18,650
5	......	......	24,000	17,000

The results of the flexure tests on steel shafting are shown in Table II. Here the nickel steel seems to withstand the combined stresses better than the mild carbon steel. This is seen by comparing the per cent. of normal elastic limit, for the carbon steel 100, 87 and 67, and for the nickel steel 100, 90, 83, 77 and 70. The per cent. of normal deflection at the center for carbon steel is seen to be 100, 92 and 79, while for nickel steel it is 100, 98, 100, 99 and 89. The modulus of elasticity is changed but little in either case, that is, the combined stresses have little effect upon the stiffness of the shafting.

Table III gives the bending moments in both torsion and flexure for both carbon and nickel steel shafting. Table IV gives the results of computing unit stresses by the various formulæ for combined stresses. The first and second columns give the greatest tension and shear, respectively, on any internal plane, when no account is taken of the change of form due to the acting stresses. The third and fourth columns give the greatest tension and shear, respectively, on any internal plane, when it is assumed that Poisson's ratio is $\frac{1}{4}$. The fifth and sixth columns give the greatest tension and shear, respectively, on any internal plane, when it is assumed that Poisson's ratio is $\frac{1}{3}$. The last two columns give the

TABLE IV.

UNIT STRESSES (Computed from Different Formulæ).

Kind of stress.	Apparent stresses.		True stresses. $I=\frac{1}{4}$		True stresses. $I=\frac{1}{3}$		Simple stresses.	
Steel Tubing in Tension-Torsion.	q_1	q_s	T_1	T_s	T'_1	T'_s	p	p_s
Simple Tension........	21,000	10,500	21,000	*13,100*	21,000	*14,000*	21,000	00,000
Simple Torsion.........	10,500	10,500	13,100	*13,100*	14,000	*14,000*	00,000	10,500
$\frac{1}{3}$ Tens.-E. L. Torsion ..	11,500	8,000	12,600	10,000	13,000	*10,600*	7,000	7,200
$\frac{1}{2}$ Tens.-E. L. Torsion ...	13,400	8,200	14,100	10,200	14,400	*10,000*	10,500	6,300
.69 Tens.-E. L. Torsion .	15,300	8,300	15,600	10,300	15,400	*11,000*	14,000	4,500
.81 Tens.-E. L. Torsion .	17,600	9,100	17,700	*11,300*	17,800	*12,100*	17,000	3,300
1.00 Tens.-E. L. Torsion	*21,300*	*10,800*	*21,300*	*13,500*	*21,400*	*14,400*	21,000	2,700
Steel Tubing in Compression-Torsion.								
Simple Compression	24,000	12,000	24,000	*15,000*	24,000	*16,000*	24,000	00,000
Simple Torsion	10,500	10,500	13,100	*13,100*	14,000	*14,000*	00,000	10,500
$\frac{1}{3}$ Comp.-E. L. Torsion ..	12,600	8,600	13,800	*10,800*	14,200	*11,500*	8,000	7.700
$\frac{1}{2}$ Comp.-E. L. Torsion ..	13,500	7,500	13,800	9,300	14,000	10,000	12,000	4,500
.83 Comp.-E. L. Torsion	20,700	*10,700*	20,800	*13,300*	20,900	*14,200*	20,000	3,800
1.00 Comp.-E.L. Torsion	*24,300*	*12.300*	*24,400*	*15,400*	*24,450*	*16,400*	24,000	2,000
Steel Shafting in Torsion-Flexure.								
Mild Carbon Steel.								
Simple Flexure........	47,000	23,500	47,000	29,300	47,000	*31,300*	47,000	00,000
$\frac{3}{4}$ Tors.-E. L. Flexure...	*51,160*	*30.660*	*53,700*	*38,300*	*54,500*	*40,800*	41,000	22,800
$\frac{4}{4}$ Tors.-E. L. Flexure...	*40,600*	*34,100*	*54,200*	*42,600*	*55,700*	*45,400*	31,000	30,400
$\frac{5}{4}$ Tors.-E. L. Flexure...	*71,200*	*59.900*	*83,300*	*74,900*	*87,400*	*79,900*	22,500	38,000
Nickel Steel								
Simple Flexure........	76,500	*38,200*	76,500	*47,800*	76,500	*51,000*	76,500	00,000
$\frac{2}{5}$ Tors.-E. L. Flexure...	72,200	37,700	73,000	*47,100*	73,200	*50,200*	69,000	15,200
$\frac{3}{5}$ Tors.-E. L. Flexure...	71,800	*39,200*	73,060	*49,060*	73,600	*52,300*	64,000	22,800
$\frac{4}{5}$ Tors.-E. L. Flexure...	71,800	*42,300*	75,000	*52.900*	76,100	*56,400*	59,000	30,400
$\frac{5}{5}$ Tors.-E. L. Flexure...	73,600	*46,600*	*78,500*	*58,200*	*80,100*	*62,100*	54,000	38,000

unit tension and unit shear on the outer fiber applied to the specimen during the test. In the case of the compression-torsion tests the first, third, fifth and seventh columns give unit compression instead of unit tension. (For the formulæ from which these results have been computed reference is made to a former communication of the author, see Vol. VI, p. 295.)

CONCLUSIONS.

The results of tests reported in this paper show:

(1) That combined tension and torsion lowers the elastic limit in torsion, as shown in Fig. 8.

(2) That combined compression and torsion lowers the elastic limit in torsion, in about the same way as in the case of tension-torsion.

(3) That combined torsion and flexure lowers the elastic limit of the materials in flexure, as shown in Figs. 7 and 8, and that this lowering seems to be less than for any other case of combined stresses, thus far investigated. This lowering is slightly less for the nickel steel shafting than for the carbon steel shafting.

(4) That the unit deformation at the elastic limit of the tubing in tension-torsion and compression-torsion is lowered, as shown in Fig. 9.

(5) That the deflection of the steel shafting is made less when the torsion is increased, the change being greater in the case of the carbon steel than in the case of the nickel steel. (Deflection here means deflection at the elastic limit.) A comparison of Figs. 5 and 6 shows, that within the limits of elasticity, the amount of deflection for any given load is about the same for the carbon steel as for the nickel steel.

(6) That the modulus of elasticity, both in torsion and flexure, is lowered slightly by the presence of combined stresses (Fig. 9).

(7) That the maximum shear on any internal plane should control in design of parts subjected to combined stresses. In Table IV the computed maximum tension and maximum shear that is greater than the tensile or shearing strength of the material has been underlined. It is seen that in only a few cases does the maximum tension exceed the tensile strength of the material, while the computed maximum shear is, in very many cases, greater than the shearing strength of the material. These results are generally in accord with results previously obtained by the writer.

TESTS OF STAYBOLTS AND STAYBOLT IRON.

BY E. L. HANCOCK.

During the past year, a series of tests of staybolts and staybolt iron have been carried on, under the direction of the writer in the laboratory for testing materials of Purdue University. Inasmuch as this subject is now occupying the attention of one of the committees of this Society, it was thought that the results of the tests made would be of interest and value. The investigation, which was quite independent of the work of the Committee, was divided into two parts: (1) An investigation of the effect of varying the length and tensional stress of hollow staybolts upon their resistance to vibration; (2) An investigation of the relative strength of solid and hollow staybolt iron of the same grade.

MATERIAL.

The staybolt iron, both solid and hollow, was one inch in diameter, the hollow having a hole in the center 0.38 inches in diameter. The bars were purchased on the market from a prominent manufacturer, who was requested to furnish uniform material. The order called for solid and hollow staybolt material of the same grade. In furnishing the material the manufacturer claimed that the solid and hollow bars were exactly of the same material, the hollow bars being produced by rolling the solid bars, increasing the strength and flexibility of the material and making it more uniform in structure. Direct tension tests showed the material to have the following physical properties:

	Yield point.	Maximum strength.	Per cent. elongation.	Per cent. contraction.
Hollow material.....	31,700	44,700	27 (in 8 in.)	34
Solid material	33,160	44,600	25 (in 8 in.)	38

METHOD OF TEST.

An Olsen vibratory machine was used in making the test. This machine is so constructed that one end of the staybolt may be rigidly clamped, while the other end is caused to move in a circle of

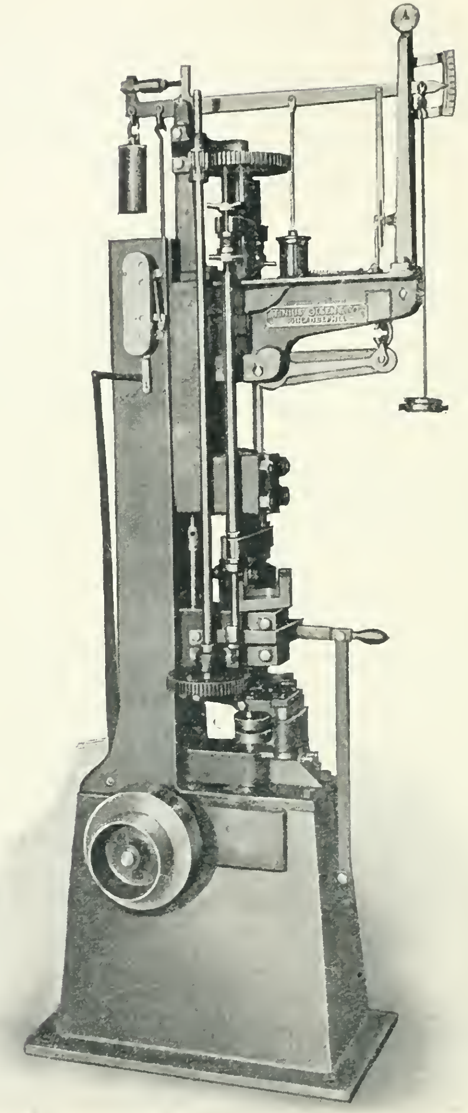

FIG. 1.—Machine for Making Vibratory Tests.*

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*A diagrammatic drawing of this machine is given in Vol. IV, p. 322.

desired radius. Provision is also made for the application of desired tensional loads, making it possible to vibrate the material while under tension. The machine (Fig. 1) is familiar to most engineers and needs no further description here. The test specimens were prepared in accordance with Fig. 2.* About five inches was allowed at one end for clamping in the machine, and about three inches at the other for the fitting on the ball, by means of which vibration was possible. The length of the staybolt was given as the distance from the lower end of the clamp to the center of the ball. Three groups of hollow staybolts, having lengths of 5, 6 and 7 inches, respectively, were prepared, these were threaded with standard staybolt dies, 12 threads to the inch. They were tested in such a way that one end of the bolt vibrated in a circle $\frac{1}{4}$ inch diameter, at the rate of 120 revolutions per minute. In each group specimens 1, 2, 3, 4 and 5 were vibrated under tensional stresses of 4,000, 6,000 8,000, 9,000 and 10,000 pounds per square inch, respectively. Two other groups, one of hollow and one of solid staybolt iron, were prepared. These pieces, which were all 8 inches long, were left unthreaded but were grooved just at the lower edge of the clamp. They were vibrated through the same distance as those just described and at the same speed, the tensile stresses varying from 4,000 to 10,000 pounds per square inch in each case. While the tests were being made, observations were made of the number of revolutions for certain increments of elongation, as indicated by the machine. These elongations, while not the actual elongations, serve to show something of the behavior of the material while under these tests.

RESULTS.

The sections of the broken specimens are shown in the photographs, Figs. 3 and 4. Fig. 3 shows the fractured ends of the threaded bolts of Series 1, 2 and 3. The fact that the load and length varied in the different specimens is not apparent in the fractures. All have a characteristic crack, extending on each side of the center toward the outside. Fig. 4 shows the fractured ends of the unthreaded bolts of Series 4 and 5. The specimens in these series were grooved at the lower edge of the clamp. An examination of the fractures shows the same single crack, extending from the center outward, in the hollow bolts. The fibers of the solid bolts do not seem to be so well united. If the materials were originally the same the process of making the material hollow seems to

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* Acknowledgment is made to *The Railway Age* for the cuts used in this paper.

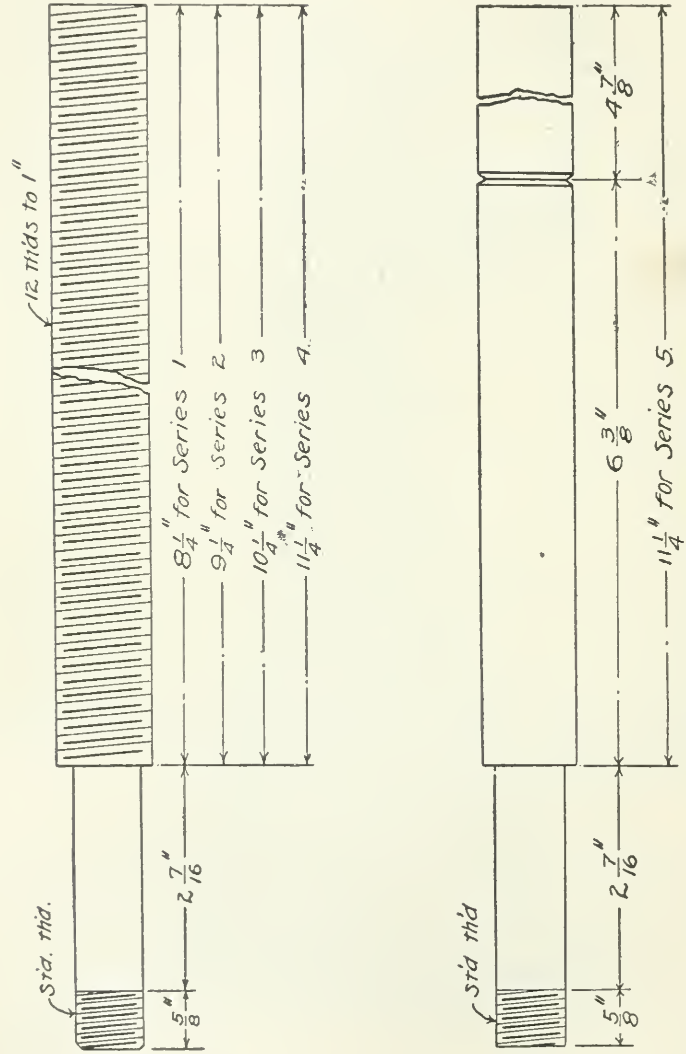

12 thds to 1"
$8\frac{1}{4}$" for Series 1
$9\frac{1}{4}$" for Series 2
$10\frac{1}{4}$" for Series 3
$11\frac{1}{4}$" for Series 4
$2\frac{7}{16}$"
$\frac{5}{8}$"
Std. thd.
$4\frac{7}{8}$"
$6\frac{3}{8}$"
$11\frac{1}{4}$" for Series 5
$2\frac{7}{16}$"
$\frac{5}{8}$"
Std thd

FIG. 2.—Drawing of Staybolts Tested.

have united the fibers, so that separation takes place only in one plane. There seems to be no change in the fracture due to change in tensile load and the fractures of the threaded bolts do not differ noticeably from those of the grooved bolts.

Table I gives the numerical results of all tests made. It is seen that the percentage of contraction of area was greater for the threaded bolts than for those that were not threaded and greater for the unthreaded hollow than for the solid. The per cent. of elongation, of the original length, is seen to vary in about the same way. It should be remarked here, that the threaded specimens

TABLE I.

RESULTS OF TESTS OF STAYBOLTS AND STAYBOLT IRON.

Specimen.	Length of bolt. Inches.	Diameter at base of thread.	Diameter of hole.	Tensile stress. Lbs. per sq. in.	Revolutions to rupture.	Per cent. of elongation.	Per cent. of contraction of area.	Revolutions to point A.	Revolutions from A to B.	Elongation to point A.	Elongation to point B.
Hollow Staybolts, Threaded.											
1–1	5	.82	.38	4,000	1,126	.4	28.5	....	....	....	....
1–2	5	.81	.38	6,000	1,898	4.5	29.9	....	....	....	....
1–3	5	.82	.38	8,000	1,783	6.3	25.5	....	....	....	....
1–4	5	.81	.38	9,000	2,853	5.1	29.9	....	....	....	....
1–5	5	.82	.38	10,000	1,426	4.5	28.5	....	....	....	....
2–1	6	.83	.38	4,000	1,920	1.0	27.2	....	....	....	....
2–2	6	.82	.38	6,000	2,324	3.1	28.5	....	....	....	....
2–3	6	.82	.38	8,000	3,365	3.6	28.5	....	....	....	....
2–4	6	.81	.38	9,000	4.161	4.1	29.0	....	....	....	....
2–5	6	.82	.38	10,000	5,183	4.1	28.5	....	....	....	....
3–1	7	.85	.38	4,000	4,223	.7	23	500	3,500	.025	.04
3–2	7	.85	.38	6,000	5,280	.9	23	500	4,000	.04	.06
3–3	7	.85	.38	8,000	4,858	1.5	23	750	3,750	.08	.15
3–4	7	.83	.38	9,000	4,613	1.6	27	750	3.500	.12	.18
3–5	7	.82	.38	10,000	6,507	1.6	28.5	500	6,000	.11	.18
Solid and Hollow Staybolt Iron, Grooved.											
4–1	8	.91	.38	4,000	1,519	.4	11.5	150	1,200	.019	.032
4–2	8	.92	.38	6,000	1,041	.5	9.5	150	750	.013	.026
4–3	8	.92	.38	8,000	1,213	.5	9.5	150	900	.023	.045
4–4	8	.90	.38	9,000	1,994	1.3	13.6	150	1,650	.038	.070
4–5	8	.92	.38	10,000	1,683	.5	9.5	300	1,200	.038	.051
5–1	8	.93	...	4,000	1,660	.5	7.7	150	1,350	.007	.021
5–2	8	.95	...	6,000	2,201	.4	3.4	150	1,800	.012	.027
5–3	8	.94	...	8,000	2,638	.4	5.4	300	2,000	.03	.043
5–4	8	.93	...	9,000	1,717	.9	7.7	150	1,200	.025	.045
5–5	8	.87	...	10,000	1,367	.9	1.9	150	900	.03	.055

NOTE.—The elongations given for the points A and B are those recorded by the machine and not the actual elongations.

required constant reclamping in order to preserve the original length, on account of the continued crushing of the tops of the threads. There was no slipping of the bolt in the clamp. Comparing the last two series of tests, 4 and 5, it is seen that the solid bolts required the greatest number of vibrations to rupture them; that they contracted less and elongated less. Fig. 5 shows graphically the increase in the number of vibrations, to rupture, as the length increased. It should be observed that the outer fibers of the bolts at the lower edge of the clamps were overstrained when the tests were started, due to the great eccentricity under which the tests were made. Assuming a modulus of elasticity of 28,000,-

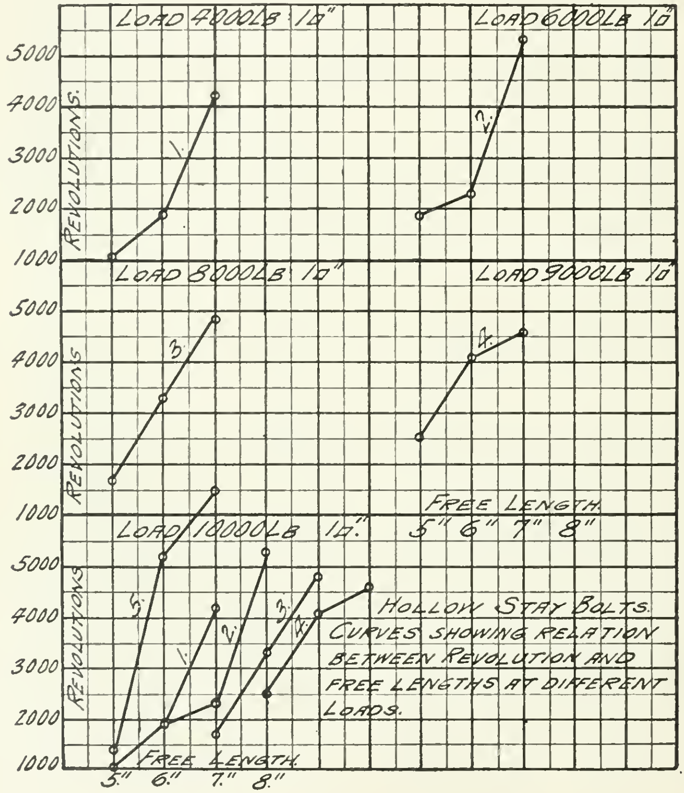


FIG. 5.

000 the fiber stress, due to flexure alone, is found to be in every case greater than 70,000 pounds per square inch. The actual fiber stress would be much less than this since the formula does not hold true beyond the elastic limit.

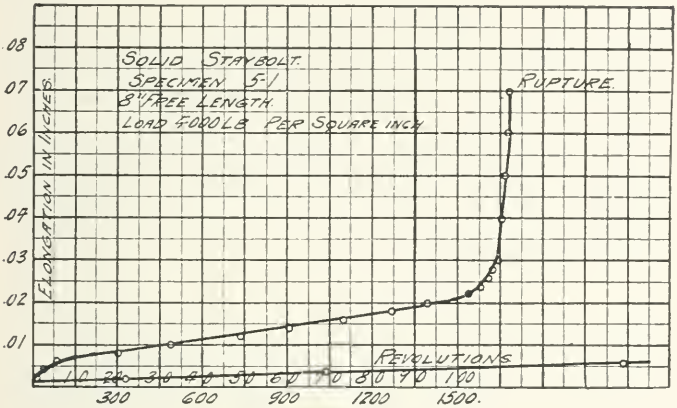


FIG. 6.

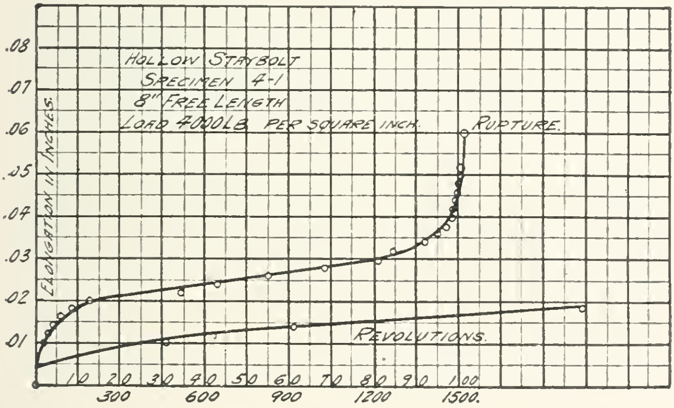


FIG. 7.

Figs. 6 and 7 show the relation between the elongation, measured by the machine, and the number of revolutions. These are only two typical curves selected from the total number taken. The lower line in each case represents the first few points, drawn to a magnified horizontal scale. All curves obtained showed a rapid elongation at first, up to a point which we may call A. Beyond this point elongation took place much more slowly to a point B, when the piece elongated very fast to rupture. These points A and B are not as definitely marked in Figs. 6 and 7 as they are in the other cases where the tensile stresses are greater. This first elongation is greater in the hollow than in the solid bolts and greater for increased tensile stress for both, as will be seen by consulting Table I. It seems reasonable to believe that this first elongation up to the point A, takes place while the bolt is being stressed beyond its yield point. After being overstrained throughout its cross-section, it elongates less rapidly up to the point B, when the outer fibers have reached their maximum strength. The bolts then elongate rapidly until rupture occurs.

CONCLUSIONS.

The results of the tests show, (1) that the fibers in the hollow iron seem to be more firmly united than in the case of the solid iron, as shown by the fractures; (2) that increasing the length of the threaded bolt increases the number of vibrations to rupture, even when the tensile stresses are increased, (3) that grooved solid staybolt iron requires a slightly greater number of vibrations to rupture it, than the hollow, and that it contracts less and elongates less. (4) That the material shows a point of yielding and a maximum point.

In closing, the writer wishes to acknowledge the efficient way in which Mr. I. W. Scott and Mr. C. A. Esslinger, senior students in Mechanical Engineering at Purdue University, assisted in carrying out the tests reported in this paper.

COMPRESSIVE AND TRANSVERSE TESTS OF STEEL CONNECTING RODS.

BY GAETANO LANZA.

The following is an account of three sets of tests of steel connecting rods for locomotives, their object being the determination of the ultimate compressive strength per square inch, and of the modulus of rupture.

Twenty rods, all of I section, were furnished by the Baldwin Locomotive Works, together with the holders needed to mount those in the testing machine, that were to be tested in compression, with the usual pin ends of practice. Fourteen were subjected to direct compression and six to a transverse load. The tests were made in the Laboratory of Applied Mechanics of the Massachusetts Institute of Technology, under the direction of the writer, partly by Mr. R. A. Wentworth, and partly by Mr. C. A. Merriam, for their graduating theses.

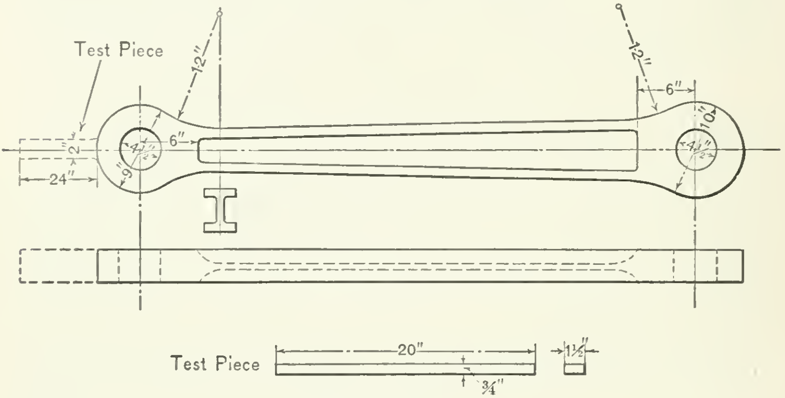
In the first of the three series, eight rods were tested under direct compression, each of them having for its least section approximately seven square inches and for its greatest section approximately eight square inches.

Their ratios of length (center to center) to least radius of gyration were respectively 100.5, 109.4, 118.4, 125.0, 130.0, 134.8, 139.7, and 149.4, their lengths from center to center in inches being respectively 89.38, 98.38, 107.38, 111.75, 116.25, 120.63, 125.13, and 134.13.

The quality of the metal in each case was determined from specimens cut from pieces forged on the ends of the rods for this purpose. The tensile strength of the steel in pounds per square inch, as thus determined, varied from 77,840 to 81,660, while its limit of elasticity, ascertained from the same specimens, varied from 37,730 to 49,440 pounds per square inch.

The compressive strength per square inch of least section obtained from the tests of the rods varied from 36,100 to 40,600 pounds.

In the second series six rods were tested in compression, the ratio of length to radius of gyration being, in all cases, approximately 130. They were so designed that the thickness of the flanges was $\frac{11}{16}$ of an inch, while the width of the flanges was, in the first five 4 inches, and in the last 4.25 inches. The thicknesses of web, in the first five, were respectively $\frac{7}{16}$ in., $\frac{13}{32}$ in., $\frac{3}{8}$ in., $\frac{5}{16}$ in., and $\frac{1}{4}$ in., and in the last $\frac{5}{16}$ in. The tensile strength of the steel, in pounds per square inch, varied from 68,170 to 75,600, while the elastic limit in pounds per square inch varied from 24,340 to 32,390. The compressive strength per square inch of least section obtained from the tests of the rods, varied from 26,400 to 32,390 pounds.



Design of Rod.

In the third series six rods were subjected to transverse loads. They were approximately duplicates of those of the second series, except that, instead of having eye ends they were of I section throughout their lengths, which were, in each case, eight inches greater than the lengths from center to center of the corresponding rods of the second series, thus allowing them to extend four inches over their supports at each end.

The tensile strength of the steel in pounds per square inch varied from 65,420 to 76,000, while the elastic limit in pounds per square inch varied from 25,750 to 32,190. The modulus of rupture obtained from the transverse tests of the roads varied from 41,210 to 49,990 pounds per square inch.

The following tables and figures give the essential details of the rods, and a summary of the results of the tests.

ACTUAL DIMENSIONS OF RODS.

First Series—Compression.

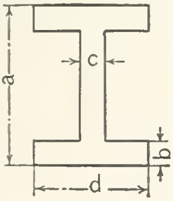
Rod.	Cross Head End.					Crank End.			
	Length C. to C.	a	b	c	d	a′	b′	c′	d′
A	89.375	4.54	0.79	0.56	3.50	6.62	0.80	0.48	3.50
B	98.375	4.54	0.795	0.54	3.52	6.63	0.85	0.49	3.51
C	107.375	4.58	0.77	0.44	3.50	6.60	0.77	0.45	3.51
D	111.75	4.55	0.80	0.56	3.51	6.64	0.79	0.54	3.52
E	116.25	4.52	0.82	0.57	3.50	6.53	0.82	0.57	3.51
F	120.625	4.54	0.795	0.55	3.51	6.61	0.79	0.47	3.49
G	125.125	4.54	0.78	0.53	3.51	6.63	0.80	0.53	3.51
H	134.125	4.54	0.815	0.54	3.50	6.61	0.81	0.52	3.50

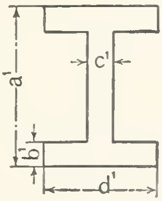
Second Series—Compression.

1b	132.25	5.18	0.69	.425	4.01	6.33	0.69	.425	4.01
2b	133.00	5.24	0.70	.415	4.01	6.41	0.69	.412	4.01
3b	131.50	5.96	0.69	.365	4.01	7.15	0.70	.370	4.01
4b	134.05	5.97	0.70	.315	4.02	7.17	0.70	.310	4.02
5b	136.85	5.99	0.70	.265	4.01	7.17	0.70	.265	4.01
6b	142.50	6.21	0.69	.310	4.26	7.49	0.70	.315	4.26

Third Series—Transverse.

1a	132.25	5.09	0.69	.425	4.02	6.42	0.69	.450	4.00
2a	133.00	5.15	0.70	.410	4.01	6.49	0.70	.415	4.02
3a	131.50	5.88	0.70	.360	4.00	7.21	0.69	.389	4.02
4a	134.06	5.89	0.70	.290	4.02	7.22	0.69	.315	4.01
5a	136.80	5.89	0.70	.265	4.00	7.24	0.69	.270	4.00
6a	142.50	6.13	0.70	.300	4.26	7.57	0.69	.315	4.27





SUMMARY OF ALL COMPRESSION TESTS ON CONNECTING RODS.

Rod.	Length center to center of pin holes. Inches.	$\frac{l}{\rho}$ (Least sect.)	Area.		Tensile Properties of the Steel.					Breaking Strength. Lbs. per sq. in. of Rod.	
			Least section. Sq. in.	Mean section. Sq. in.	Elastic limit. Lbs.	Tensile strength. Lbs. per sq. in.	Elongation in 8 in. Per cent.	Contraction of area. Per cent.	Modulus of elasticity. Lbs. per sq. in.	Least section.	Mean section.
A	89.38	100.5	7.19	7.60	37,730	80,280	25.8	30.9	28,000,000	38,700	36,700
B	98.38	109.4	7.19	7.78	45,650	78,830	20.8	34.1	28,300,000	40,600	37,500
C	107.38	118.5	6.73	7.21	43,900	77,840	20.4	42.5	30,000,000	39,300	36,700
D	111.75	125.0	7.27	7.78	47,560	79,270	22.3	43.2	28,500,000	36,100	33,700
E	116.25	130.0	7.38	7.96	45,820	79,250	...	...	30,500,000	39,300	36,400
F	120.63	134.8	7.21	7.55	49,440	81,660	24.1	39.9	28,800,000	39,300	37,500
G	125.13	139.7	7.06	7.67	39,590	79,690	24.4	45.5	30,300,000	38,000	35,000
H	134.13	149.4	7.28	7.78	39,470	78,650	21.0	28.3	30,800,000	37,400	35,000
1b	132.25	129.6	7.141	7.388	26,310	69,290	29.0*	50.9	27,900,000	29,410	28,420
2b	133.00	130.1	7.192	7.433	24,340	72,140	25.8*	46.5	26,560,000	26,420	25,560
3b	131.50	129.6	7.278	7.310	27,380	72,500	28.2*	46.7	27.050,000	31,600	31,460
4b	134.05	129.4	7.050	7.236	25,720	68,170	30.2*	53.4	....	26,400	25,720
5b	136.85	130.4	6.823	6.980	30,500	74,740	25.4*	38.0	27,200,000	32,390	31,660
6b	142.50	129.4	7.464	7.662	26,750	75,600	24.6*	37.6	25,810,000	28,750	28,010

*Elongation in 5 in.

DISCUSSION OF THE RESULTS.

A perusal of the results of the first series of tests shows that, within the range of dimensions of the rods tested, the value of the ratio of length to least radius of gyration has no apparent

SUMMARY OF TRANSVERSE TESTS ON CONNECTING RODS.

Loads Applied at Center.

Rod.	Distance between supports. In.	$\frac{l}{\rho}$ (Least sect.)	Area.		Moment of inertia of mean section.	Tensile Properties of the Steel.					
			Least section. Sq. in.	Mean section. Sq. in.		Elastic limit. Lbs. per sq. in.	Tensile strength. Lbs. per sq. in.	Elongation in 5 in. Per cent.	Contraction of area. Per cent.	Modulus of elasticity. Lbs. per sq. in.	Modulus of rupture of rod. Lbs. per sq. in.
1a	132.25	129.7	7.16	7.45	38.73	.....	.....	...	...	....	44,120
2a	133.00	129.6	7.16	7.44	40.07	31,110	76,000	22.4	24.5	....	49,990
3a	131.50	129.9	7.20	7.46	51.91	25,750	67,970	28.6	38.2	28,410,000	44,180
4a	134.06	129.1	6.93	7.14	51.66	32,190	65,420	29.0	37.3	....	41,210
5a	136.80	130.7	6.78	6.96	51.37	28,160	75,250	22.6	24.0	28,760,000	41,440
6a	142.50	129.6	7.38	7.54	60.29	30,000	......	25.2	25.3	....	45,130

influence upon the ultimate compressive strength per square inch, and hence that, for any given quality of steel, the same value can be used for the ultimate compressive strength for any of the ratios included in the series.

The rods of the second and of the third series were made of steel having a lower tensile strength and a lower tensile elastic limit than the steel used in the first series, and the results show lower values for the ultimate compressive strength of the rods. As no transverse tests were made upon rods constructed of the steel used in the first series, no comparison can be made of the moduli of rupture corresponding to the different kinds of steel.

The table on the next page gives a comparison of the ultimate compressive strength of the rods with the tensile elastic limit, and with the ultimate tensile strength of the steel used, and it appears that the ultimate compressive strength in the case of the lower steels is generally somewhat greater than the tensile elastic limit, while with the higher steels, it is generally somewhat less, but that higher tensile strength and elastic limit are generally accompanied by higher compressive strength.

No tests were made of the steel under alternate stress, but

Distinguishing mark.	Tensile elastic limit of Steel. Lbs. per sq. in.	Compressive strength of rod. Lbs. per sq. in.	Ratio of compressive strength to tensile elastic limit.
2b	24,340	26,420	1.09
4b	25,720	26,400	1.03
1b	26,310	29,410	1.12
6b	26,750	28,750	1.08
3b	27,380	31,600	1.15
5b	30,500	32,390	1.06
A	37,730	38,700	1.03
H	39,470	37,400	0.95
G	39,590	38,000	0.96
C	43,900	39,300	0.90
B	45,650	40,600	0.89
E	45,820	39,300	0.86
D	47,560	36,100	0.76
F	49,440	39,300	0.80

Distinguishing mark.	Ultimate tensile strength of Steel. Lbs. per sq. in.	Compressive strength of rod. Lbs. per sq. in.	Ratio of compressive strength to tensile strength.
4b	68,170	26,400	0.39
1b	69,290	29,410	0.42
2b	72,140	26,420	0.37
3b	72,500	31,600	0.44
5b	74,740	32,390	0.43
6b	75,600	28,750	0.38
C	77,840	39,300	0.51
H	78,650	37,400	0.42
B	78,830	40,600	0.51
E	79,250	39,300	0.50
D	79,270	36,100	0.46
G	79,690	38,000	0.48
A	80,280	38,700	0.48
F	81,660	39,300	0.48

it is reasonable to suppose that the steel used in the first series would have shown higher results in such a set of tests than would have been obtained with the steel used in the second series.

TENSION TESTS OF STEEL ANGLES WITH VARIOUS TYPES OF END-CONNECTIONS.

By Frank P. McKibben.

The tests which form the subject of this paper were made upon thirty-three steel angles such as are used for tension members in riveted framed structures. They are a continuation of a series made at the Massachusetts Institute of Technology in 1906 and described in Volume VI, p. 267, of the Proceedings of the Society. This series of tests (begun last year and not yet completed) has been undertaken with a view of studying the following points:

1. The ultimate strength of the angles in tension.
2. The value of a lug in transmitting stress from the outstanding leg of the main angle into the hitch plate.
3. The relative strength of angles where the gauge line for rivets and where the center of gravity line, respectively, pass through the center of the pull.
4. The effect of the position of the rivets connecting the main angles to the hitch plates.
5. The relative strength of single angles and angles riveted together to form pairs.
6. The effect, upon the strength of the specimen, of the different methods of holding the specimen in the testing machine.

In the series tested this year there are three specimens of each of ten different types, also three specimens which differ from one another, and from one of the ten types only slightly. This makes thirty-three angles in all. These are shown in detail in Figure 1.* Each of the main angles, 5 ft. 4 in. in length, is riveted at each end to a hitch plate.

The description of the different types tested is as follows:

Type A_3. One $3\frac{1}{2}$ in. x 3 in. x $\frac{3}{8}$ in. angle, connected at each end by six rivets, three in each leg; with lugs and with the gauge line passing through the center of pull.

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*Acknowledgment is made to the *Engineering News* for the cuts used in this paper.

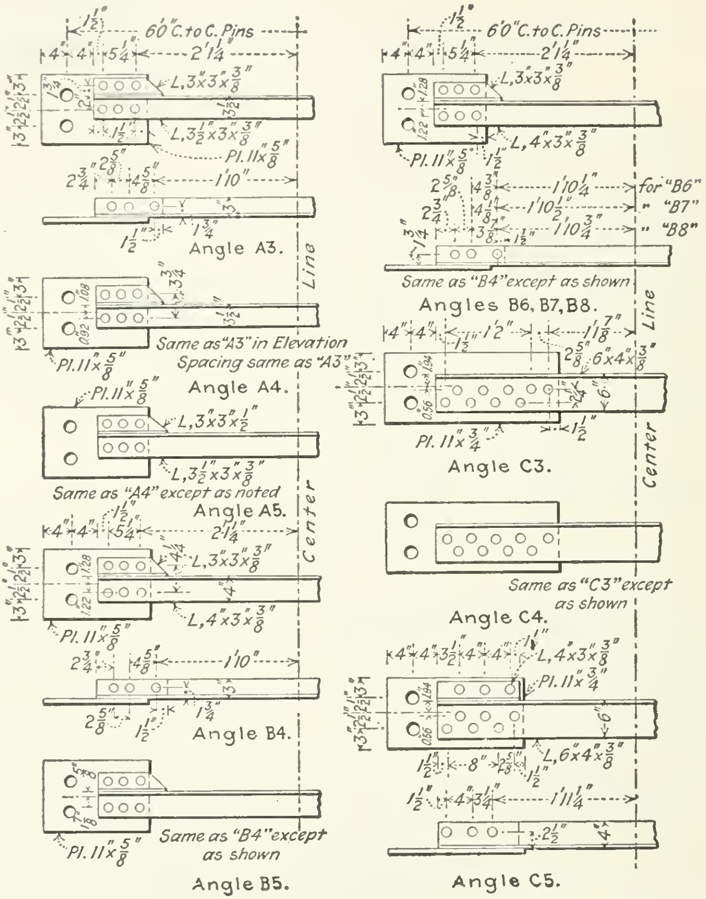

Fig. 1.—Test Specimens Used in 1907 Tension Tests of Steel Angles.

Note: Three specimens of each type were tested, except B_6, B_7 and B_8, which were represented by only one specimen each. Angles and plates were of medium steel, Manufacturers' Standard. All angles of a given size were cut from one long angle. All rivets were of rivet steel, $\frac{7}{8}$–in. diameter, holes punched $\frac{15}{16}$–in. Pin-holes were drilled to 2–in. diameter. (See following page for cut 1a.)

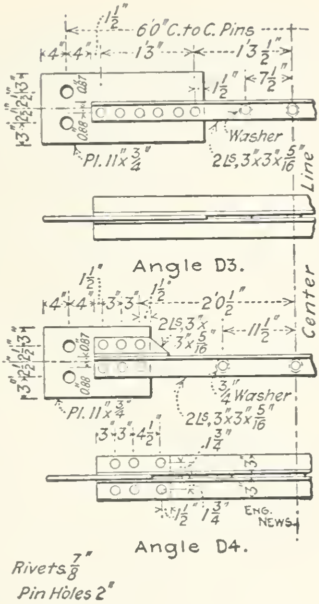

Fig. 1a.

Type A_4 same as A_3, except with center of gravity line, in plan, passing through center of pull.

Type A_5 same as A_4, but with thicker lug angles.

Type B_4 similar to A_4, but with 4 in. x 3 in. x $\frac{3}{8}$ in. main angles.

Type B_5 similar to B_4, but with center of pull passing, in plan, $\frac{5}{8}$ in. from back of vertical leg.

Types B_6, B_7, B_8 same as B_4, but with staggers between the two inner rivets decreasing successively by one quarter of an inch.

Type C_3. One 6 in. x 4 in. x $\frac{3}{8}$ in. angle connected to each hitch plate by nine rivets staggered in two rows in the 6 in. leg, but with both inner rivets on the gauge line nearest the back of the angle. Center of gravity line passes through center of pull.

Type C_4 same as C_3, except that the two inner rivets are on alternate, instead of on the same gauge line.

Type C_5 similar to C_4, but with lugs; six rivets in 6 in. leg and three rivets in 4 in. leg at each plate.

Type D_3. Two 3 in. x 3 in. x $\frac{3}{8}$ in. angles, one on each side of the hitch plate and connected, without lugs, to each plate by six rivets all in one row. The center of gravity line passes through center of pull.

Type D_4 similar to D_3, but with lugs; each main angle is connected at either end with 3 rivets in each leg.

Improvements upon the types of connections used in the 1906 series of tests were attempted in the following ways: (1) By increasing the stagger between the two inner rivets, in cases where there were rivets in both legs of the angle, until the minimum net zigzag area of the angle through two rivets was at least equal to the net right section. (2) By placing the two inner rivets on the inner gauge line in specimens having two rows of rivets in the leg connecting with the hitch plate. (3) By applying the pull to the specimen through the center of gravity line of the angle in plan. (4) By using thicker lug angles.

The connections of the angles to the hitch plates were so designed as to insure failure in the angles rather than in the rivets or connecting plates. The hitch plate at each end of each specimen was provided with two 2 inch holes, by means of which it was pinned between two holding plates which in turn were connected by a single pin to a third plate gripped by the testing machine. A drawing of this holding device may be found in Volume IV and need not be reproduced here. It should be borne in mind that the holding device is a flexible joint, and is not the rigid connection more commonly found in structures in which angles are used as tension members. The method of holding the ends has an important bearing on the strength of the angles, and the presence of this flexible joint should not be lost sight of in studying the results of the tests thus far made. The writer hopes to make further tests in which a rigid connection is to be used.

Table I gives the results of the physical tests of small tensile test bars which were cut from the long angles out of which were taken the main angles of the specimens tested this year. In most cases *three* such test bars were taken from each long angle but in two cases only *two* bars were secured from each long angle. On all of these test pieces the yield point was determined by the drop of the beam and also by measurement with dividers.

In Figure 2 are shown diagrammatically the outlines of the fractures, all of which occurred in the main angles. The numbers on the sketches indicate the sequence of the ruptures. With the exception of specimen number 57, made of two 3 in. x 3 in. x $\frac{5}{16}$ in. angles, failure occurred at one of the inner rivets which connects the main angle to the hitch plate, that is, the connecting rivet which lies nearest to the center of the specimen. In the case of specimen number 57 one of the angles failed at the inner connecting rivet but the other angle failed at the first tack rivet 8 in. from the inner rivet. In every case the fracture started at a rivet. In the majority of cases of specimens having lugs, failure occurred on a zigzag section passing through rivets in the horizontal and in the vertical legs. This was the case even though the minimum net zigzag section was slightly larger than the net right section, as for example, specimens 31, 32, 33. In some of the specimens having the two net sections just mentioned nearly equal, for instance numbers 35 and 37, the fracture really occurred on the zigzag section but it also started on the right section. Failure occurred on the right section in some cases. In many specimens the angle failed by shearing on the diagonal section between the inner rivets in the horizontal and in the vertical legs after the metal between these rivets and the outer edges of the legs had been broken. The fractures were all silky. In specimen No. 50 a slight flaw was detected after failure at the inner rivet in the leg

TABLE I.—Physical Properties of Small Test Bars Cut from Steel Angles. Series of 1907.

No.	Mark.	Original area.	Per sq. in. Lbs.		Elongation per cent. in 8 in.	Reduction of area. Per cent.
			Yield point.	Ultimate strength.		
1	AA3, AA4.......	.558	35,500	57,900	29.1	57.0
2		.555	35,500	57,800	28.6	53.3
3		.558	35,300	57,600	28.6	54.7
Mean		.557	35,400	57,800	28.8	55.0
4	AA5............	.554	36,100	56,500	29.6	56.3
5		.552	34,700	56,600	29.0	54.5
6		.557	34,700	56,500	28.9	49.7
Mean		.554	35,200	56,500	29.2	53.5
7	BB4, BB5, BB7.	.567	35,000	53,500	29.2	58.6
8		.568	34,300	53,400	31.9	59.3
9		.569	35,100	54,000	30.9	58.2
Mean		.568	34,800	53,600	30.7	58.7
10	BB6, BB8.......	.565	35,400	59,500	27.0	50.4
11		.564	33,700	60,000	28.0	48.6
12		.559	36,900	59,900	27.4	54.4
Mean		.563	35,300	59,800	27.5	51.1
13	CC3, CC4, CC5...	.573	36,900	59,800	31.3	55.2
14		.573	37,600	59,300	27.1	57.1
15		.570	38,400	59,600	27.9	54.7
Mean		.572	37,600	59,600	28.8	55.7
16	DD3.	.463	39,000	60,200	25.9	49.3
17		.467	38,900	59,600	26.8	51.2
Mean		.465	39,000	59,900	26.4	50.3
18	DD4.	.455	38,400	58,800	30.3	50.8
19		.460	39,100	58,800	28.5	56.5
Mean		.458	38,800	58,800	29.4	53.7

attached to the plate. The specimens made of two angles failed more suddenly than those made of one.

Table II is a summary of the tests of the specimens; numbers 1 to 27 inclusive being those tested in 1906 and previously published, and numbers 28 to 60 inclusive are those tested this year.

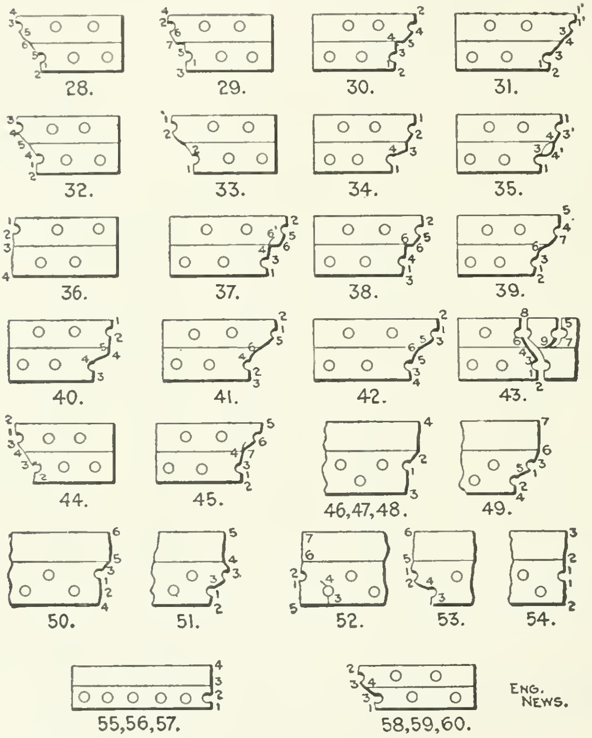

Fig. 2.—Sketches of Fractures of Steel Angles Having Various Types of End Connection.

Note: Small figures at fractures denote origin and progress of rupture. The lower portion of each sketch represents the leg connected to the hitch-plate.

The figures in the columns headed "Per cent. of Ultimate Strength Developed" are obtained by dividing the strength per square inch in the specimen by the ultimate strength per square inch of the small test bars and multiplying by 100 to reduce to a percentage basis. Net areas have been computed under the assumption that the holes are $\frac{15}{16}$ in. in diameter and again that they are 1 in. in diameter. The least zigzag sections have been computed by assuming the angles to be developed about the corners and taking the net areas on a section passing from the edges of the legs to the

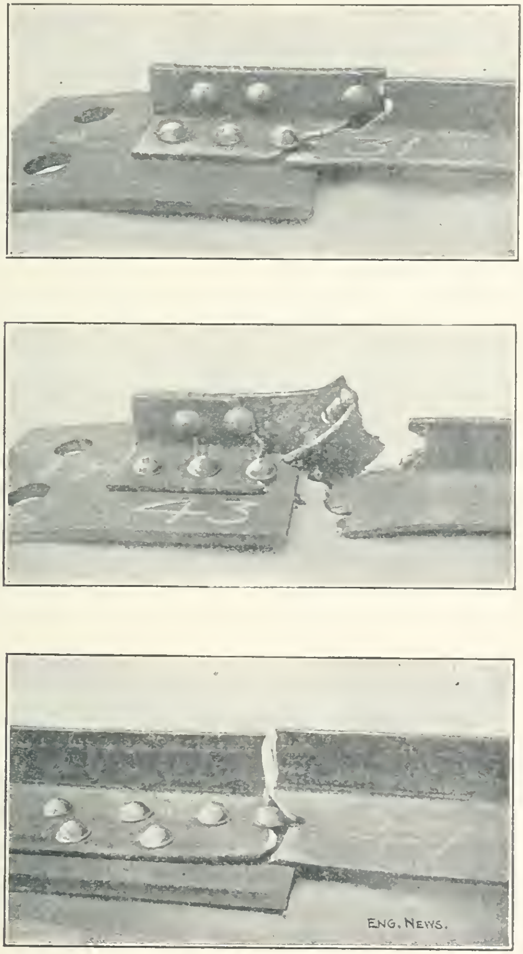

Fig. 3.—Three Typical Fractures.

centers of the inner rivet holes, then diagonally between centers of rivets. In the results published last year the net areas given were not the least zigzag areas, but were those computed on sections which approximated the fractured sections. In the Table II last year's tests have been *revised* so that the net zigzag areas shown are the least that can be obtained for those tests.

In studying the results of these tests it should be remembered that the ends of the specimens are not held rigidly in the testing machine and that there are a comparatively small number of angles of any one kind. However, the results, so far as they go, should be studied with a view of determining the most efficient connection. The efficiency of a specimen may be based upon its gross area or upon its minimum net area. This latter area may be either that of a right section or that of a zigzag section. On the whole it seems most reasonable to base the efficiency on the gross area of the angle so that if we have a series of angles of the same size, gross cross-section and quality, but with different end connections, that connection is the most efficient which will allow the angle to carry the maximum load. Basing our study therefore on the stress per square inch of gross area of the angles, and considering all of the angles of a given size, the tests seem to show that for the $3\frac{1}{2}$ in. x 3 in. x $\frac{3}{8}$ in. angles the greatest efficiency, 76.4 per cent. occurs with those angles, with lugs having the pull passing through the center of gravity of the angle in plan. Inasmuch as the efficiencies of the specimens A_3, A_4 and A_5 are about the same, and are much greater than those of A_1 and A_2 tested last year, it appears that this gain in efficiency is due largely to the increased stagger of the inner rivets in the two legs of the angles. The importance of this stagger is seen by comparing A_3 and A_2. Of the specimen A_3, A_4 and A_5 the last two, both of which have the center of pull coinciding with the center of gravity instead of with the gauge line, show the greatest efficiency.

For the 4 in. x 3 in. x $\frac{3}{8}$ in. angles the greatest efficiency is obtained from B_4 and B_5, which make a much better showing than the angles of the same size tested last year. The advantage of having the large stagger between the inner rivets of the two legs will be noticed by comparing an efficiency of 77.4 per cent. for B_4 with an average of 73.4 per cent. for B_6, B_7 and B_8. In B_4 the average net right section is less than the average net zigzag section while for B_6, B_7 and B_8 the reverse is true.

For the 6 in. x 4 in. x $\frac{3}{8}$ in. angles the greatest efficiency for this year's tests is shown for C_3 which has no lugs, has the first two rivets on the same gauge line and the line of pull through the center of gravity of the specimen. However, a slightly better showing was made by C_2 of last year's series. C_2 had lugs and had the center of pull passing through the inner gauge line of the main angle.

Of the specimens composed of two 3 in. x 3 in. x $\frac{5}{16}$ in. angles the greatest efficiency is shown by this year's tests with 68.9 per cent. for D_3, which has no lugs and which has the center of pull passing through the center of gravity of the angles.

Acknowledgment of obligations is hereby made to Messrs. Arthur L. Davis and S. P. Waldron of the American Bridge Company for the specimens tested, to Messrs. A. F. Holmes, instructor, and H. B. Hastings and F. W. Morrill, students, at the Massachusetts Institute of Technology, for attending to the work in the laboratory.

IRON CASTINGS: SOME CAUSES OF FAILURE IN SERVICE.

By Robert Job.

Every manufacturer and user of iron castings from time to time meets difficulty owing to defects in the iron, and in order to reduce fractures, discards, and unsatisfactory service to the minimum, it is of great importance to know definitely the cause of the defects in order to apply the proper remedy. In the course of every-day practice for many years, the writer has been interested in making a careful study of these matters as an aid in working out the most economical methods of manufacture and in securing the greatest efficiency in the output, and it may be of interest to give some details which have been observed from time to time.

In many foundries to-day, as was the case in one which first came under our attention fifteen years ago, the practice is to purchase a number of different grades of iron, not by analysis, merely by brand,—and to mix these in the cupola, with the object of obtaining special virtue from the combined properties of the metals. The underlying reason for this plan is simply that one brand runs high in silicon while another contains an excess of manganese, and still another is high in phosphorus making the iron very fluid, and very weak. The inherent defects of this method of mixing are well known to every foundrymen, for difficulty is found in keeping up shipments of each of the different brands, and even when they are in stock, it is by no means an easy matter to get a correct mixture in the cupola even under the most favorable conditions. In consequence the foundryman is troubled by irregular quality of castings, and it is difficult to maintain proper control of the output, simply because there is great difference in the composition of the iron from day to day and even in different parts of the heat, when the intention has been to make a uniform grade of castings. Part of this variation is due to the differences in the composition of different lots of a given brand of iron. For example, we have known of different shipments of one brand which have ranged from 0.8 per cent. to 1.5 per cent. of phosphorus, while another showed an equal range in its manganese contents, and still another has varied from 2 to 5 per cent. in silicon. Under such conditions it is obviously out of the question to expect uniform results in the product, for at one time the iron is strong and tough, while soon afterward it is weak or brittle, or is full of blow-holes and porous, and the foreman who under the best of conditions is none too free from troubles, finds himself in serious difficulty.

In order to secure uniformly good results it is obviously essential at the start to have in the finished casting a composition which will give the properties needed in service, and also adapted to the conditions of casting. Many service failures in the writer's experience have been caused directly by this neglect to obtain a uniform composition suited to the service. We remember particularly instances in which locomotive cylinders and wheel centers failed within a short time, and on investigation it was found that the proportion of phosphorus averaged nearly one per cent. while the silicon was over two and one-half per cent. As a consequence, the iron was so weak that little tenacity under impact could have been expected, although the price paid for this grade was considerably higher than the market rate for quality far better adapted to the service.

In order to put a stop to these conditions under our own practice, a careful study was made to determine both the composition and physical condition and structure which gave the best service under different classes of requirements, and to determine the means necessary to secure this quality in the output. In many cases of failure we found that the difficulty was due wholly, or in large part, to the presence of blowholes or to porosity or sponginess of the iron, and at times to the presence of considerable proportions of oxide of iron and cinder in the iron. Any of the latter conditions, of course, were direct indications of defective foundry practice and where they existed, defective composition was also often present.

In the daily routine of our foundry, general locomotive castings were made ranging all the way in size from locomotive cylinders and wheel centers to small castings about one quarter inch thick, and most of the castings required machining in some part.

In view of this wide variation in size and conditions of service, some doubt was felt whether a single grade of pig iron would meet the requirements. At the outset, however, we drew up specifications for a strong medium iron and upon receipt of each shipment sampled and tested each carload before acceptance, to be certain that it was of the desired quality. The same practice was also adopted with reference to our coke supply, and the proportion of ash and of sulphur were held down to reasonable amounts. At the same time methods of treatment of the iron in the ladle and in the cupola were introduced to decrease hardness and to remove oxide of iron and blowholes, and to incease the fluidity and density of the iron. As a result of these changes excellent results were obtained from the very start. The single grade of iron with the careful control of the quality, gave a degree of uniformity which had never before been possible, and by means of systematic treatment the properties of the iron could be varied as far as was desirable for the different purposes.

In the machine shops the change had an immediate effect, for hard castings, "porous iron" and blowholes almost entirely disappeared. Within a few months breakages in service had fallen off to a very marked extent owing to the toughening of the iron, and at the end of a year the scrap coming in was insufficient for the needs of the foundry. In order to better keep track of the service, we stamped each wheel center as it was cast, with the date, and after a lapse of three years not a single one had been broken in service,—a most marked contrast from the former conditions.

In the course of our routine work we found comparatively little difficulty in maintaining the desired quality in the shipments of the pig iron and the coke, though we soon learned that the systematic test of each carload of the raw materials was essential to ensure proper quality of the product, for at one time a carload of weak iron would be kept from service, and at another time iron which would have produced hard and brittle castings. Still again, coke would not be accepted which proved to be deficient in heating value or was of such quality that hard castings would have resulted. By means of the method of purchase under specifications the cost of the pig iron was decreased, and in the foundry the proportion of discards was cut down owing to the fluidity of the iron resulting from the cleansing of the metal from oxides and slag, and to the increased strength and toughness of the product.

From what has been said it will be evident that there is a definite cause for each of the defects which commonly cause difficulty in service or in the foundry, and it will be seen that these may be very largely removed by means of systematic control.

DISCUSSION.

Mr. Forsyth. MR. WILLIAM FORSYTH.—I would like to ask the author if he would do away entirely with scrap in his locomotive practice, in making locomotive castings. There is a large surplus of scrap which is ordinarily used in the foundry, and as I understand the author he would use pig iron entirely.

Mr. Job. MR. ROBERT JOB.—In our mixtures the practice was to use fifty per cent. scrap.

Mr. Forsyth. MR. FORSYTH.—Under that condition I don't see how he could control the quality.

Mr. Job. MR. JOB.—We realized that the composition of scrap was liable to very wide variations indeed; and consequently took the very worst limits which we found in actual practice and figured from that; so arranging the limits in the specifications for pig iron, that under even the most unfavorable conditions as to scrap, the quality of the product was well adapted to the service requirements.

Mr. Moldenke. MR. RICHARD MOLDENKE.—I should like to call attention to one point in the paper just read. I am glad to see that the author recognizes the oxide of iron as one of the impurities of cast iron. In the course of my experience I have run across many difficulties which could not be charged to the regulation causes, and which on elimination of every ordinary factor, left the presence of the dissolved oxide as the only probable cause of the particular trouble. Thus with the composition correct; silicon and phosphorus as well as sulphur normal; with the coke of good quality and composition, yet castings would sometimes result which had blow holes under the skin which could only be attributed to an occluded gas coming out at the moment of set. Now for the solution of the difficulty.

I always felt a little disinclined to use high manganese in the pig-iron, because the burning out of manganese was just so much unnecessary loss. But now that so much steel scrap is used in foundry practice, it is different. The fact that high percentages of steel go in the mixture, sometimes as high as 40 per cent., means that the iron that comes out in the ladle is very low in total carbon and consequently its melting point is very high; or nearer **Mr. Moldenke.** the point of steel practice, in which ferro-manganese is the great purifier. I have seen cases where 4 per cent. of ferro-manganese was added in the ladle, where 40 per cent. of steel scrap was used in the cupola, and 3 per cent. of the manganese disappeared and left 1 per cent. in the casting and this very free from holes. So that the question of oxidation has become now better recognized than formerly, and I think the tendency to-day is, instead of using all the ferro-manganese in the ladle, that some of the manganese is introduced in the pig-iron, when oxidation troubles are exhibited.

THE HISTORY AND DEVELOPMENT OF THE ALLOY PRACTICE IN THE UNITED STATES AS APPLIED TO RAILWAY BEARINGS.

By G. H. Clamer.

In the earliest days of railroading, the alloys used for bearings were those which had been used in general machine construction; the favorite alloy seemed to be copper and tin. This alloy was adopted, not because it had any particular merits which were proven, but because it had given satisfactory results on stationary engines, etc., and this is all that was apparently known about it. Besides it was about the most expensive combination of the common metals which could be made, and this was sufficient endorsement of its excellence. Furthermore, the prevalent idea in those days was to make an alloy as hard as possible. It was well known that tin, when added to copper, hardened it greatly, so, naturally, as much tin was added as was possible without making the alloy too brittle. Consequently, bearings were made with tin as high as four parts copper to one part tin, or 80 per cent. copper and 20 per cent. tin (in reality, bell metal), and from this on down to nine parts copper to one part tin, or 90 per cent. copper and 10 per cent. tin. Seven parts copper and one part tin for many years was considered the standard of excellence—that is 87½ per cent. copper and 12½ per cent. tin—and is still specified by some few railroads, although these specifications are seldom enforced, as the mixture to-day is considered entirely too expensive.

In those days, that is before 1870, the equipment was light, and speeds so slow that almost any kind of bearings would answer the purpose, and then, again, a few hot boxes en route were expected, and a traveler would consider himself fortunate should he reach his destination without detention, due to this cause; he had not been spoiled by any of the present day possibilities. He was content to take dinner in Philadelphia, and breakfast in New York; the idea of dining in Philadelphia and breakfasting in Chicago was beyond his wildest dreams.

The American Master Mechanics' Association was formed in the 60's the object of this association being to bring men together who are working in the mechanical field of railroad operation, the prime object being to agree on standards of construction. The American Master Mechanics' Association devotes attention more particularly to those problems which have a bearing upon the motive power department. The Master Car Builders' Association was formed somewhere about the same time for the purpose of standardizing construction of car equipment; the methods of handling, manufacturing, etc. Neither of these associations, so far as I know, have ever considered the materials of construction, their work being confined to the mechanical end only, *i. e.*, design, shop practice, etc.

The American Society for Testing Materials has for its object the filling of this gap, *i. e.*, the consideration of materials of construction, and although its field extends beyond the railway field yet a great deal of its work, so far, has been confined to strictly railway materials, namely, rails, wheels, axles, etc. There still remain a number of materials of construction which have as yet had no consideration, among them, bearing metals.

The Railway Master Car Builders' Association in 1872 adopted its first standard design of bearing. Before that time no standard whatever was recognized; each master mechanic or car builder had his own idea as to the design of bearing, and consequently the equipment included bearings of almost every conceivable design. Naturally no interchange was possible, in fact, the interchange was only then becoming necessary because of cars being taken from one road to another. The standard size then adopted was 3¾ x 7 inches. This was the largest bearing then in service, and to the manufacturer, who previously had been accustomed to bearings 3 x 6, 2½ x 5, etc., the 3¾ x 7 appealed as a huge bearing. The sizes of the standard axle and journal have been increased from time to time to meet the demand for heavier equipment, and this has necessitated larger journal brasses. The Master Car Builders' Association have adopted a standard brass for each size axle, differing, however, only slightly from the original design. Fully 95 per cent. of the cars being built to-day are equipped with bearings of Master Car Builders' standard design. Although the design of bearing adopted by the Master Car Builders'

Association may not be, and in all probability is not, the best design of bearing which can be devised, it is at once evident that standardization of equipment is of vital importance. Cars are to-day sent from Maine to Texas, and from coast to coast, operating for months on a foreign road. Were it not for the standardization of equipment, cars might be held up for long periods at far away points, because the road, in whose custody it is, has not the proper equipment to repair it.

I have apparently drifted somewhat from the subject of my paper, but have introduced this short history of the Master Car Builders' design of bearing because of the influence the design, size, weight and speed of rolling equipment have upon the selection of the present alloys used, and because nothing whatever has been done toward the standardization of alloys used for bearings, and the only condition noted in the valuation of bearings in interchange of railroads is whether it is solid brass, filled, or iron back type of bearing, whereas a great difference exists in the value of the bearings, depending on the composition, a good bearing often being given for a poor one, and vice versa.

Coming back to the alloys used for railway bearings, a copper and tin alloy, made in the proportion of seven parts copper and one part tin, was until 1887 considered the standard alloy for railway bearings. This standard was maintained principally for the reason that the manufacturer of railway bearings, for seventeen years before that time, had practically been in the hands of one company—the company of Mr. D. F. Hopkins. Hopkins, in 1870, invented his lead-lined car bearing. This invention consisted of nothing more than the application to the bearing surface of a thin lining of lead. The lining he applied by first tinning the journal surface of the bearing and then placing it against a mandrel, and pouring as thin a lining as possible of pure lead between the bearing and the mandrel, the molten lead attaching itself firmly to the tinned surface of the bearing. Hopkins thus produced what he called a self-fitting bearing.

Because of the constantly increasing weight and speed of trains about the time of Hopkins' invention, the bearings were becoming more and more troublesome. The trouble was aggravated by the fact that bearings used were hard and unyielding, being made of the before-mentioned alloy of copper and tin (in the proportion of 7 parts copper to 1 part tin) and were ready to heat under the slightest provocation. Then again the lubrication was by no means so satisfactory as it is to-day, and dust-guards were little used. The invention of Hopkins, like many others of just the same simple nature, solved the difficulty in a remarkably satisfactory manner, and so evident were its merits that it was in a very short time almost universally used. Patents were pronounced valid by both the Eastern and Western Railroad Associations, and Hopkins had a practical monopoly of the trade. A few of the railroads who made bearings at their own foundries sent them to Hopkins to be lead lined. Other manufacturers who made bearings were also compelled to send them to him for lead lining before the railroads would use them. As is usual in such cases where monopolies are had, the consumer pays a long price for his product. Hopkins could always get his price, and although he had every opportunity in the world to cut the cost of his product by the addition of lead or zinc to his bearings, he rigidly maintained the use of the copper and tin alloy.

Before the expiration of the Hopkins patent, Dicks, in England, took out a patent on the introduction of lead and phosphorus into the copper and tin alloy for bearings, claiming that the lead added to its efficiency. This is the alloy still largely used, and known as standard phosphor-bronze bearing metal. This alloy, under the patent of Dicks, was manufactured by the Phosphor-Bronze Smelting Company, and became known as the "S" Brand —other alloys, containing phosphorus, being manufactured for other purposes. The "S" Brand Phosphor Bronze, having a composition of a trifle over 79 parts copper, 10 parts tin, 10 parts lead, and a little less than 1 part phosphorus, was adopted by the Pennsylvania Railroad, as a result of a series of tests made by Mr. J. W. Cloud, Engineer of Tests. Mr. Cloud proved what had already been a fairly well-founded supposition, *i. e.*, that the addition of lead to the copper and tin alloy was really of very material benefit, not only in so far as the liability toward heating was concerned, but that it also decreased the rate of wear. The phosphorus was added for its supposed beneficial influence in the foundry. Phosphorus, as is well known, is a great deoxidizer, and has the property of rendering the metal which contains it exceedingly fluid. As a result of these experiments and further study, a specification was drawn up, which was, so far as I am aware, the first specification covering the composition of an alloy for railway bearings. The specification was that of the Phosphor-Bronze "S" Bearing Metal, and described certain limits for each constituent, and a limitation on impurities. It read as follows:

Copper	78 to 80
Lead	8 to 11
Tin	9 to 11
Phosphorus	$\frac{7}{10}$ to 1 per cent.

Sometime after the introduction of the phosphor-bronze bearing metal, my father, Mr. F. J. Clamer, commenced the manufacture and sale of metal containing

77	parts	copper,
11½	"	tin,
11½	"	lead,

without the use of phosphorus. This was about the year 1876. After selling this product in a very limited way, he interested the Elkins Manufacturing Company, but it was found hard sledding to introduce it. First, because of the prevailing prejudice against anything except copper and tin, this metal being looked upon as a fraud because copper and tin was debased by lead. Second, because of the competition of Phosphor Bronze "S" Brand, which was recognized by the Pennsylvania Railroad as an alloy of merit; and, third, because the Hopkins lead-lined car bearing patent had not yet expired—the bearings of Ajax metal were not sufficiently soft to operate satisfactorily without lead lining. For engine bearings, however, it found favor, and sales increased steadily. In 1880 the manufacture and sale was taken up by the Ajax Metal Company, and the production continually increased. Some years later other manufacturers came in the field and adopted practically the same formula, calling their products by various trade names, which, together with advertisement and business push, extended sales until they reached considerable proportion. I am only considering now those alloys which have marked progress in the art of making railway bearings. Considerable amount of bearings were all the while being sold, and are still being sold, made exclusively from scrap, which are of rather indefinite composition. These I shall discuss later.

Dr. Dudley appears to be the first who has actually taken in hand a practical and scientific study of the alloys for railway bearings. During his long connection with the Testing Department of the Pennsylvania Railroad he has had occasion to study practically most of the alloys of promising qualifications which have from time to time been presented. About the year 1890 tests were conducted by the Test Department of the Pennsylvania Railroad whereby a copper and tin alloy, of seven parts copper and one part tin, was compared with the above-mentioned "S" Brand-Phosphor Bronze, composition of which is 79 parts copper, 10 parts tin, 10 parts lead, and one part phosphorus. Without discussing any of the details of these tests, which were published in the "American Engineering and Railway Journal" in 1892, I will simply quote the conclusions which were drawn from the data obtained:

FIRST.—Phosphor bronze showed less tendency to heat.
SECOND.—Phosphor bronze showed a slower rate of wear.
THIRD.—The phosphorus in the alloy apparently did not affect materially the performance of the bearings in service, and is added only for beneficial influences in the foundry.
FOURTH.—The superiority of the "S" Brand Phosphor Bronze is therefore due to the lead which it contains.

Having noted the beneficial influences of lead, it now became a question as to how much lead should be added, also what relationship did the quantity of tin have upon the properties of the alloy. With these questions in mind, further tests were conducted which resulted in the establishment of the following facts, which were published in the "Franklin Institute Journal" of 1892:

FIRST.—Wear diminishes with the increase of lead.
SECOND.—Wear diminished with the diminution of tin.
THIRD.—The tendency to become heated decreases as the lead increases and the tin decreases, or, in other words, as the plasticity of the alloy is increased.

These facts having been established by numerous tests, a still further problem confronted the experimenters, *i. e.*, it being true that the valuable properties of the alloy increased in the direction indicated, how far could the decrease of tin and the increase of lead be extended, and still maintain sufficient compressive strength, so that the bearings would not distort under the loads which they are called upon to carry. The tests conducted were with percentages of tin from 12½ to 8 per cent. and lead from zero to 15 per cent. None of these alloys showed indication of distortion in service. The alloy 8 per cent. tin, 15 per cent. lead and 77 per cent. copper proved to be the best of the series. To this a small percentage of phosphorus was added (¼ of 1 per cent.) for foundry purposes. This alloy Dr. Dudley called Ex. B. metal. Dr. Dudley, in one bold leap, then tried to make an alloy of 4 per cent. tin, 20 per cent. lead and 76 per cent. copper, but he failed in his attempt to produce a homogeneous alloy of this composition. As he expressed it, "a very funny difficulty was encountered, *i. e.*, the lead segregated," and further experiments in this line were abandoned, it being presumed that an alloy with approximately the above composition, *i. e.*, 8 per cent. tin, 15 per cent. lead, 77 per cent. copper, was the best of the series, the conclusions being that a small further diminution of tin and increase of lead which was possible would not be material. It is usually believed that lead and copper do not alloy, and can not be made into castings. It is true that lead and copper have a very weak affinity for one another, and this, combined with the great difference in the melting point, and specific gravity of the two metals, makes it impossible to get castings which can be said to be really homogeneous, unless they be small, thin sections, which can be rapidly cooled. A copper and lead alloy does not make what would be called good castings, although they may be fairly well mixed; by the introduction of tin, a more homogeneous product is produced.

It was the knowledge of these facts no doubt which led Dr. Dudley to abandon further efforts in the direction of increasing his lead and decreasing his tin beyond the proportions of Ex. B. metal. Why his efforts to make an alloy 4 per cent. tin, 20 per cent. lead and 76 per cent. copper failed it is hard to tell, as the alloy is made with the simplest kind of foundry manipulation. In all probability, when attempting to make this alloy, Dr. Dudley had present some impurity—phosphorus perhaps—which was detrimental to the result. Knowing that tin added to the homogeneity of the copper and lead alloy, it was thought by Dr. Dudley and others that the higher the amount of tin the greater would be the amount of lead which could be homogeneously combined. The segregation of the alloy, 76 per cent. copper, 20 per cent. lead, 4 per cent. tin, which he endeavored to make, he therefore attributed to the low tin content instead of impurity or foreign element.

Just at this point the work on the copper, tin and lead alloy was taken in hand by Mr. Joseph G. Hendrickson and myself. We conducted experiments first with the idea in mind of introducing some element which would cause a quick chilling or rapid setting of the metal after entering the mold. After trying additions of practically all the high melting point metals, we found that nickel was the only one which really gave satisfactory results. Nickel was found to alloy readily with copper and tin, and caused it to set quickly; at the same time, it increased its tensile and compressive strength. By the use of nickel, we were enabled to increase the lead considerably above the former standard as set by Dr. Dudley, that is 15 per cent., while still maintaining tin at 8 to 10 per cent. We also found it possible to lower the tin content, and even to entirely dispense with it, and still secure a satisfactory alloy for casting, the alloy of copper and lead being found to be more homogeneous when nickel was added than copper and lead alone, although there was not found to be any advantage to be gained by substituting nickel for tin in order to get the same amount of hardness. Further than this, we found that it was possible to make alloys with small amounts of tin and large amounts of lead without any nickel or addition of high melting point metal.

The fact that lead, in large quantities, without any nickel or other mixture or special treatment of any kind, could be added to a copper and tin alloy that is far beyond 15 per cent., with tin below 8 per cent.—the limits of Dr. Dudley's Ex. B. alloy—was an utter surprise to us, as there had always been a deeply-rooted idea in the trade that such an alloy could not be made successfully. That this idea was entirely erroneous we proved beyond doubt, and as the result of many experiments, we found that as a matter of fact it was entirely due to diminishing the tin from the previous standard, *i. e.*, 8 to 10 per cent.—that it was possible to proportionately increase the lead as the tin was diminished, stopping only at such a point with the increase in lead and decrease in tin when the compressive strength was so diminished that thoroughly practical and commerical bearings no longer resulted. This point we found to be:

Tin.................................. 5 per cent.
Lead..................................30 per cent.
Balance of the alloy, *i. e.*, 65 per cent., being copper.

This alloy is largely sold under the name of "Plastic Bronze."

It has a compressive strength of about 15,000 pounds per square inch, and is found to operate without distortion on the bearings of the heaviest locomotives in service, it being used not only for driving brasses, but also for rod brasses and bushings, in which capacity considerable thrust is encountered. It is also used in vast quantities on cars of 100,000 pounds capacity, which are the largest cars now in service.

Although it was well known, as a result of Dr. Dudley's publications, that it was highly desirable for bearing purposes to increase lead and decrease tin in copper, tin and lead alloys, not only for the added excellence of the product, but also because of the decrease in the cost of production—tin and copper being replaced by a cheaper metal, *i. e.*, lead, no one before us had apparently taken the matter in hand with deliberate intention of testing the accuracy of the prevailing idea that it was not possible to produce bearings of such an alloy. Two causes of the segregation of lead which were undiscovered were undoubtedly responsible for this erroneous theory. First, tin above a certain limit; second, presence of detrimental amounts of certain other elements existing as impurities.

All manufacturers of journal bearings, ourselves included, made frequent attempts to increase the lead. When those attempts were made, however, it was always done with the idea in mind of still further cheapening the cheapest competitive mixture which was sold, necessarily made entirely from scrap, or it was done with mixtures containing the former standard percentage of tins, 8 to 10 per cent. In both cases the results were failures. In the first case because of the presence of considerable zinc and other impurities and in the second case because of high tin.

An explanation as to why it was possible to increase the lead by diminishing the tin was found by a microscopic examination of such alloys. It is clearly shown by examining the structure of copper, tin and lead alloys that the lead is but mechanically held, the copper and tin forming a network or matrix, which acts in the capacity of a supporting structure for the lead, and gives to the alloy its strength and hardness. An examination of the copper and tin matrix shows it to be made up of what we at the time considered free copper and a chemical compound $SnCu_3$, together with eutectic alloy if the tin was sufficiently high. This eutectic alloy has a very much lower melting point than the balance of the alloy, and consequently, if present, requires a considerable period of time to solidify after entering the mold, and owing to this time required, the lead, which has a very much lower melting point even than the eutectic alloy and a very much higher specific gravity, has abundant time to liquate to the bottom of the casting, thus producing an entirely unsalable product. If, however, the tin is kept within the limits where this eutectic alloy is not formed, the whole matrix solidifies at a comparatively elevated temperature, and therefore solidifies so quickly that the lead has no opportunity to separate, the result being an entirely homogeneous alloy. The point where we found a critical change to take place in the matrix was approximately 9 per cent. tin and 91 per cent. copper. If the matrix was so proportioned that the tin remained below 9 per cent., more than 20 per cent. lead could be added with entirely satisfactory results. Furthermore, as the tin is decreased below this percentage, a correspondingly greater amount of lead could be added.

Messrs. Heycock and Neville have since made a very exhaustive examination of the copper and tin series of alloys and published in 1903 in the "Philosophical Transactions of the Royal Society in London" an important thesis on this subject. In this thesis they have located very accurately this critical point in the constitution of copper and tin alloys at 9 per cent. tin, and have described the constitution of those alloys containing less than 9 per cent. as solid solutions of copper and tin, whereas, beyond 9 per cent. they consist of solid solution of copper and tin, together with the compound $SnCu_4$. Without going into any further details of the work of these gentlemen, suffice it to say that they have confirmed our explanation as to the rational of our invention. This work has also been confirmed by several other workers in the field.

Beside the alloys so far considered, *i. e.:*

Copper and tin alloys of various proportions,
Copper, tin, lead alloy with phosphorus, proportions 79 parts copper, 10 parts tin, 10 parts lead, 1 part phosphorus, known as phosphor bronze,
This same alloy without phosphorus, known as Ajax metal, and a number of other alloys of similar composition, known by various other names,
Dr. Dudley's Ex. B. metal and Ajax plastic bronze above described,

there are a number of other compositions described in specifications of various railroads. These specifications all cover alloys with tin from 8 to 10 per cent., lead from 10 to 15 per cent., and all with various details as to limitations on the various metals and impurities and methods of inspection, etc. There has also been used continuously since about the year 1887 vast quantities of bearings which are made entirely from scrap. Such bearings as these, having a composition as follows:

Copper	65 to 75
Tin	2 to 8
Lead	10 to 18
Zinc	5 to 20

constitute from 50 to 75 per cent. of the car bearings used to-day. For engine bearings a great deal more care has been exercised, and only alloys of approved composition have been used, although within the last few years there has also been a great tendency toward the use of unknown scrap compositions even for engine bearings. This is no doubt largely due to present high cost of metals.

For the linings of car brasses there was used during the period in which the Hopkins patent remained in force only pure lead, the linings which he applied to his bearings being as thin as was possible to apply. Hopkins even went so far as to apply a thick lining of lead, and to afterwards machine it out until it was not much more than a thin film. After this patent expired, the general tendency, owing to competition, was to increase the linings, and this has also been sanctioned by a great many of the railroads because of its tendency to obtain bearings at a lower figure; but with the thickness of the linings it became necessary to add hardening metals. Antimony and tin have accordingly been added for this purpose in varying proportions. With the increase in the thickness of the linings, it became necessary to increase their hardness, and at the present time linings $\frac{5}{16}$ and $\frac{3}{8}$ inch in thickness are specified by some of the largest consumers, it being necessary, in such cases, to add as high as 15 to 20 per cent. antimony.

The bearing metal problem, as will be seen by the above, is in a very chaotic condition, and is a subject well worth the attention of this Society.

THE RAW MATERIAL SUPPLY.

By P. H. Knight and C. E. Skinner.

If it were feasible to present here a complete list of the different materials which form the component parts of the product of any large manufacturing company together with those which are consumed in the manufacturing processes, or of those which are used by any great railroad, the range and variety displayed would doubtless surprise those not closely connected with such work. The list for a company with which the writers are somewhat familiar contains not less than 850 items. This list is made up of definite and distinct classes or grades of materials, the various shapes and sizes of any class all being included as one item. The purpose of this paper is to present a few considerations involved in the procuring of a supply of raw material so large and varied. The term "raw material" will be used to cover all material purchased on which work has to be done by the manufacturing company, as copper wire, pig iron, insulating paper, brass rod, porcelain, sheet steel, cast steel, etc., or which is consumed in the manufacturing process, as cutting compounds, fuel oils, coke, etc.

From the manufacturer's point of view there are in general two sets of conditions involved in the selection of a raw material, *first*, the engineering, which requires that the material have characteristics suitable for the purpose intended; and *second*, the commercial, which requires that the material selected be one that can be obtained in sufficient quantity—preferably in the open market and on satisfactory terms.

The most convenient method for designing engineers to designate the material to be used in a particular case or to make known the conditions to be fulfilled by it, is to refer to the title and serial number of a purchasing department specification in which the characteristics of the material are described and the tests to which it must conform are specified. This presumes, of course, the previous preparation of a purchasing department specification under the general conditions governing such specifications. If specifications could be prepared that would cover all classes and grades of material required and be so worded that they would be satisfactory to all parties concerned, the work to be done in connection with the supply of raw material would be mostly of a routine nature, merely checking the shipments received in line with the requirements of the specification. Unfortunately, however, where the materials are of a very great variety, it is often quite impracticable, for many of them, to use a specification at all. In many cases materials are used by manufacturers for purposes for which they are not ordinarily designed, as, for example, the use of wrapping paper for insulating purposes. The paper maker is not usually familiar with insulating work and has no means of making tests which will indicate to him whether or not his product is satisfactory for the purpose intended by the purchaser. It is also frequently difficult to devise a test that will readily and accurately determine the suitability of a material; or, granting that such a test can be made, it may not be generally recognized by the trade, and the manufacturers of the material, not being prepared to make the tests, may not be disposed to do business on this basis. Again, while the tests may be satisfactory to all concerned, the cost of making them may be more than any probable loss or risk involved in buying without a specification.

In such cases, the obvious course is to buy a grade or brand which has a definite standing in the trade, if such can be found which shows characteristics suitable for the purpose intended. The purchaser of the material must then determine for himself whether or not the commercial variations in the brands selected are such as to interfere with his manufactured product. In some cases this method of buying by brand or grade is more satisfactory than buying by specification, especially where the commercial variation in standard materials is not too great for the use in view. On the other hand, when materials are susceptible of adulteration, competition may lead the manufacturer or dealer to adulterate to such an extent that trouble results in the use of the material. The trouble and loss which may result from the use of such adulterated goods is sometimes many times as great as the value of a month's or a year's supply of the goods in question. In a certain process a brand of shellac was used which was known to contain some adulteration and this adulteration seemed to be beneficial to this particular process. The amount of adulteration was increased in certain shipments, with the result that serious trouble was experienced in the manufacture of the product and the brand had to be abandoned for one more reliable and which could be adulterated by the user as occasion required.

It is sometimes very difficult to draw a specification so that shipments of material obtained under it from different sources will correspond close enough to each other to be satisfactory, even though each may technically fill the specification; and this also involves the question as to whether materials made by different manufacturers may be used together or must be used separately, as, for example, varnishes, glues, metals, etc.

Each material may be satisfactory for use with its special characteristics in mind, and totally unsatisfactory if mixed with other goods of the same class or if not used correctly. Consequently, the shop methods and processes involved in a large factory may be a determining factor in the use of a particular brand or brands of material. From the manufacturing standpoint it is of course, undesirable to have materials of the same general class which have to be used separately, while, on the other hand, it is undesirable to be limited to any one source of supply for a material, as this situation is quite likely to result in a higher price than would obtain with competition. Furthermore, a strike or some accident, such as a fire, might at any time entirely shut off the supply, thereby delaying the completion of apparatus and necessitating the use of some untried material. It is very desirable, therefore, to try out materials from different sources, to map out their characteristics and to determine whether or not they can be used together and under the same conditions. If this can be done the brand or grade may be placed on an approved list and the purchasing department instructed to buy from any of the approved sources, as market conditions may dictate. If, for the reasons outlined above, materials cannot be used together, but may be used as substitutes for each other, care must be taken that the supply of one brand or grade is exhausted before another is introduced, and that those interested in the use of the materials are properly instructed when, for any reason, a change from one to the other is made.

It is frequently impracticable to approve all the possible sources of supply for a given material on account of the large number, and, when this is the case, a sufficient number of sources should be investigated so that the necessary competition may be secured in the buying of the material in question. One difficulty in following out this plan lies in the fact that there may be sources of supply which have not been investigated and not approved which may be just as satisfactory as those on the approved list. In such cases commercial conditions must dictate the policy in extending the list.

In purchasing material by brands or grades or even on specification, the method of handling may be somewhat different, depending on whether the material is manufactured by the party furnishing same or whether he is only a dealer or importer. If the material is not satisfactory or if modifications are required, the manufacturer may be able to make such modifications without difficulty, as for example, a change in the flash point of an insulating oil. The dealer or importer may not be able to control such modifications and, consequently, the brand may have to be changed, as for example, a brand of tin.

The purchase of a brand of material without a specification or without investigation for approval always involves more or less risk and sometimes extra labor. This labor consists in lining up any characteristics not familiar to the workmen and in following up the troubles which may occur due to the effect of such characteristics, even though the material may become entirely satisfactory when the workmen become familiar with its use. The risk lies in the possibility that different shipments from an untried source may vary in quality, to the detriment of the completed product, or that an increase in cost of production may be caused by some variation which may escape notice in testing and inspecting the raw material. Greater familiarity with the requirements makes such a variation much less likely to occur where a material has been obtained over a long period of time from one source, even though the seller's reputation in the general trade may be in no way superior to that of others.

From the standpoint of the producers of raw materials, specifications are distinctly advantageous to firms that will not reduce the quality of their product below accepted standards in order that they may cut prices. Where several brands are approved for purchase without specifications on the basis of price only, a premium is liable to be placed on the adulteration of goods or the lowering of their quality in order to meet competition. Specifications fairly drawn and strictly enforced are a protection to honest firms against unfair competition. Specifications play so important a part in the purchase of a material that it may be worth while to give an outline of some of the steps necessary to secure satisfactory specifications and some idea of the way in which they are commonly used.

It is usually impossible for any one—no matter how familiar he may be with any particular material—to draw a specification for that material without spending considerable time in making tests and securing approval, although the idea seems to prevail among many that all that is necessary is for an engineer to write out the characteristics which he wishes fulfilled in the material in question. To be entirely satisfactory in its workings a specification must be sufficiently rigid so that any material which is unsatisfactory for the purpose intended may be rejected under the specification, and yet sufficiently broad so that material required can be secured without undue cost or delay.

Good results have been obtained by drawing a tentative specification, using all the knowledge which may be available from previous tests on the material, similar specifications in general use when such are obtainable, and keeping in mind the requirements which the material must fulfil to be satisfactory. These tentative specifications are then sent to manufacturers or dealers from whom the material may be obtained, with a query as to whether they can comply with the specification as written or what modification would enable them to furnish the material more promptly or cheaply, also whether the tests outlined are acceptable, and whether or not the specification as drawn already or as modified by their suggestions will apply to commercial brands of material on the market. A commercial product should always be aimed at in such specifications rather than a special product, which invariably costs more. In certain cases, however, it may be necessary, on account of the use to which a material is to be put, to include requirements which are not usually considered commercial, as for example, a requirement governing the resistance of steel strip when it is to be used in rheostat construction.

In the make-up of specifications for materials entering into electrical apparatus, it is found that such specifications refer mainly to mechanical dimensions and chemical and physical characteristics rather than electrical characteristics.

Occasionally a preliminary specification is accepted without objection, but more frequently changes or additions are suggested, after which there follows a process of adjustment by means of which the various interests are made to agree, as far as possible, in regard to specific characteristics and tests which will admit material from the greatest number of available sources and which will also maintain a standard of quality satisfactory to the user. Before such a specification is finally adopted, it is necessary that all parties interested in it be consulted. The purchasing agent may desire to include something in regard to the basis on which unsatisfactory material may be rejected; the storekeeper may be interested in the size of package and how they shall be marked; or the superintendent may wish to insert a clause that will lessen the labor in handling the material in the shop. The final copy, including all the suggested changes and additions it is thought advisable to incorporate in the specification, is then sent to the manufacturers or dealers for their final approval. Experience has demonstrated that frequent consultation with those who are to supply the material is very advantageous, as it promotes a better understanding of the situation on the part of all concerned and avoids much of the friction that would otherwise occur in regard to the acceptance of shipments. If the purchasing company issues its specifications without such consultation, a misunderstanding of their intent may cause the sellers to either increase their price or even refuse to compete for the business.

Although a specification may have been adopted and put into operation, it cannot be called completed until after a considerable period of time has elapsed. Our President, Dr. Dudley, has already called attention to the fact that the maker of a specification for a material that has previously been bought without specification may consider himself rather fortunate if the specification does not need to be revised in some six or ten months after it has been issued. One of the reasons for the necessity of revision is that, while it is very easy to write a specification which can be understood, *it is very difficult to so word a specification that it cannot be misunderstood*, and the writers of specifications are sometimes astonished to find how many meanings can be placed on a phrase or sentence which they had believed to contain but one meaning. It also sometimes occurs that a small detail which was considered satisfactory when the specification was drawn will prove to be quite unsatisfactory in practice. A recent specification for round steel bars stipulated that the heat numbers and maker's initials should be stamped at one end of the bar. This provision met with no objection in the preliminary stages either from the manufacturers of the material or from those interested in its use in the factory. After the specification had been in force for some time the men in the shop complained that great difficulty was experienced in locating the numbers on the bars in large piles because the stamping, while done at the end of the bar as specified, was on the cylindrical surface. A change in the specification which required that the marking be placed on the flat surface of one end of each bar, removed this difficulty. This was relatively of small importance, but neglect to make the change would have caused a great deal of inconvenience and unnecessary labor. The case is illustrative of the unforeseen ways in which a specification may fail to give complete satisfaction, and it also shows why considerable time is required for seasoning in the preparation of a good working specification. This case is also illustrative of the difficulty of expressing a simple statement so that it cannot be misunderstood.

There is a third class consisting of those materials which can only be partially covered by a specification. These materials are of such nature, or the conditions surrounding their use are such, that, with any tests practical enough to adopt in a specification, it is not certain that material conforming to the specification will be satisfactory in service. On the other hand, practical tests may be known, such that non-compliance with them will conclusively prove that the material is unsatisfactory, so that a specification based on such tests has a certain value in a negative way. These materials are best handled under a combination system of approved brands and specifications in which the sellers of the materials guarantee them to meet the prescribed tests, and the buyer buys only those brands that have been found satisfactory in his business.

Copies of purchasing department specifications are given to inspectors of raw material for their guidance in accepting or rejecting shipments. Every specification should contain a clause giving the company the right to reject any material which does not conform to any and every requirement in the specification, but many specifications cover points which, while deserving consideration, are not always of primary importance, as for example, the size of packages, the method of packing and marking, and sometimes also the shapes and sizes of the material itself. For the further guidance of the inspectors, therefore, it is convenient to issue inspection specifications for their use in connection with the purchasing department specification. These specifications should designate the provisions in the purchasing department specifications which must be rigidly enforced under all circumstances, and also the provisions which in case of non-compliance may be passed over with a request to the sellers of the material to follow specification more closely in future shipments.

There may be other requirements in the purchasing department specification, non-compliance with which would unfavorably affect the cost of production in the factory, but would in no way affect the completed apparatus. In this case the inspection specification should require the inspector to reject a shipment only when there is a sufficient amount of the material in the storeroom to supply all needs until another shipment can be received.

A rigid inspection of a large quantity of raw material causes considerable expense and as certain classes of defects in some materials will appear, if they exist, when the material is handled in the factory, it is sometimes advisable to omit inspection when the material is received. To permit this, the purchasing department specifications must be so drawn as to admit of returning the material for credit whenever defects appear. As an illustrative case, consider the quality of hardness in magnet wire. This quality is not detrimental to completed apparatus but it is very objectionable to the winders and, as they are certain to discover it, the inspectors need not be required to examine each reel for hardness.

Another feature of the raw material supply which should be considered is that of samples of materials which the producers submit for investigation in the hope of securing new business. The number of such samples coming to the writers' attention in the course of a year is some thousands. These cover almost every class of raw material, hardware, manufacturing supplies, etc., and the labor and expense involved if all were tested as desired by those furnishing the materials would be very considerable. Many of the letters accompanying such samples are merely to the effect that the sample is submitted for test and no information is given regarding the characteristics of the material submitted, and there is apparently no knowledge on the part of the producer of the material as to whether it would meet any of the requirements of this general class of materials as used by the company to which it is submitted. Other letters frequently convey no idea of the application of the material, simply stating that it is meeting with universal favor, and, this being the case, they assume that there is no reason why it should not be immediately purchased in large quantities by the manufacturing company. Samples are frequently of mailing size, and often quite insufficient for satisfactory tests. Even the name applied to some of these materials is frequently so designed as to afford no clue to its proper classification. This is especially true of the new grades of insulating materials, which are sometimes designed as proprietary trade names. The number of new materials brought out during the past few years in this line has apparently been so great and the name-makers have been so crowded that a list of some of these names would sound like the reading of a telegraphic code.

The manufacturing company necessarily derives great benefit from testing and investigating the samples which it receives; many of them give valuable information and start investigations that lead up to the adoption of a material possessing superior qualities or economical advantages. It is probably not desirable to have the number of such samples diminished, but it is very desirable to have each sample accompanied by all information bearing on its characteristics, uses, etc., which the sender can obtain. This information should cover not only the commercial points of prices, deliveries, etc., but also the name of the class of materials to which the sample belongs, its most prominent characteristics, and the principal uses to which the material has been put, also specifying the results of tests—physical, chemical or electrical—to which the material has already been submitted. Such information would often enable immediate decision to be made as to whether a material is worth investigating or whether it has any application in the work of the manufacturing company, while the lack of such information sometimes results in the rejection of a valuable material after preliminary tests to determine its suitability for a purpose for which it was never intended.

To get the full benefit that may be derived from handling and testing a large variety of materials, it is very desirable to have a clean, well-lighted room fitted up with shelves, cases, bottles, etc., in which samples, properly labeled, may be filed in numerical order. An alphabetical card index should be kept of the samples, each bearing the serial number, history, characteristics, results of tests, and any special information of interest in connection with a sample. The collection should include new materials having valuable characteristics, standard materials regularly used in production, and samples illustrative of undesirable characteristics that have caused failures in regular service.

Such an exhibit gives engineers and draftsmen, at any time, a convenient opportunity to see the materials they are required to specify and to learn their characteristics. It prevents waste of labor caused by unnecessary duplication of tests as, in the course of a year or two, attention may be asked for several different samples of the same or similar material not readily recognized as such. A comparison of new samples with the permanent exhibit would frequently show such striking similarity to samples previously tested and rejected as to clearly indicate the futility of making tests on the sample in hand.

In the case of materials bought on "approved brands," without specification, it is especially desirable to have on file a sample of the shipment that was originally tested and approved, to serve as a standard for comparing with future shipments; and in the case of material bought wholly on specification some well mounted samples, of material which is known to comply with the specification, are useful in showing representatives of new firms the appearance of the material wanted.

THE NATIONAL BUREAU OF STANDARDS.

By S. W. Stratton.

Early in the history of our Government an office of weights and measures was established in connection with the Coast and Geodetic Survey of the Treasury Department, for the purpose of providing suitable standards of length in connection with its surveys. At about the same time it became necessary for the Secretary of the Treasury to adopt standards of mass and capacity and to provide copies of the same for use at the various custom houses, thus increasing the functions of the office to include mass and capacity. Later the Secretary was directed by the Congress to provide copies of these standards of length, mass, and capacity to the various States. This work was necessarily delegated to the Office of Weights and Measures. Precision measurements of length necessitated the adoption and comparison of thermometric standards of ordinary range and accuracy. During the last years of the Office of Weights and Measures it had begun in a very small way the testing of standards of electrical resistance and electromotive force, but owing to the limited facilities of the office its work was practically confined to the necessities arising in connection with the work of the Treasury Department.

In urgent and important cases comparisons with the standards adopted by the Treasury Department were made for other Departments of the Government and for the public, although no provision was made directly for that purpose. In the meantime the scientific, manufacturing, and commercial interests of the country had assumed great proportions. Accurate measurements were being employed where before guesswork and rules of thumb were considered quite sufficient. Scientific work and the introduction of scientific methods of manufacturing necessitated accurate methods of measurement. The dissemination of scientific knowledge and the adoption of the interchangeable method of manufacturing made the use of uniform working standards imperative, a result to be obtained only through primary standards of the highest type and a central institution provided with the facilities for their comparison with secondary and working standards.

It was not until 1901 that our government took steps to provide suitable standardizing facilities, although the necessity for such work had been recognized for many years. In fact the demand for it had become so great that for some time previous to the establishment of the National Bureau of Standards we were compelled to avail ourselves of the facilities of foreign governments; principally those of the Physikalisch-Technische Reichsanstalt of Germany, an institution to which too much credit cannot be given for having demonstrated the value of such institutions founded on broad scientific principles. At that time this country had assumed a creditable position in physical science and possessed some of the best laboratories in the world; it was leading in the manufacture of electrical and other machinery, and in many industries involving standards and methods of measurement. To be compelled to ask foreign laboratories for standards and standardizing facilities was clearly a situation that needed to be corrected, hence provision was made by Congress for the establishment of an institution equipped and authorized to deal with questions pertaining to standards, measuring instruments, physical constants, and the properties of materials. Funds were appropriated for the construction and equipment of laboratories and for a small scientific force, with a view to increasing the latter as soon as the laboratories were completed.

Since it would require at least two to three years for the planning and building of the laboratories, temporary quarters were at once secured in connection with the quarters formerly occupied by the Office of Weights and Measures; the planning of the laboratories was begun, as well as the selection of the scientific staff, and the development of some of the more important methods of testing. The first and one of the most important problems which presented itself was the selection of a site. After a careful examination of all the sites available one was found in the northwest section of the suburbs of Washington which was sufficiently near the city and lines of transportation to be reasonably easy of access, and which possessed the desired physical qualifications. It is large enough for immediate purposes, containing about seven acres, but steps have been taken towards securing sufficient adjacent property to protect the Bureau from mechanical and electrical disturbances that may arise with the future development of the city.

The selection of the site was naturally followed by the designing and constructing of the buildings. It was decided to erect two buildings, one of which should contain the mechanical plant, instrument shop, and other work requiring heavy apparatus; the other, a physical laboratory, situated at some distance from the first, and as far as possible free from machinery or mechanical disturbances. The amount appropriated for the buildings would not permit of ornamental or expensive construction; nevertheless it was sufficient to erect two strong, substantial, fireproof buildings, of dark red brick, trimmed with buff Bedford limestone, and of a style well suited for laboratories.

To provide for the future growth of the Bureau, it is proposed to erect several additional buildings, one of which will be a laboratory devoted exclusively to the investigation of the properties of and methods of testing engineering, building, and other materials; another will provide quarters for the electrical work; and another will be devoted to the work in chemistry. These sections of the Bureau's work have already been organized in the present buildings, but with reference to their final disposition in buildings erected especially for the purpose. The entire group of buildings will be supplied with heat, power, light, and other facilities from the mechanical laboratory.

The personnel of the Bureau has been gradually increased from fourteen at its organization to one hundred and ten for the coming fiscal year. Over 75 per cent. of the personnel consists of scientific and technical men, the selection of which presented a difficult problem owing to the high standard that must be maintained by the Bureau, and the great demand for the same classes of men by educational institutions and the engineering professions. Nevertheless, the Bureau from the beginning has insisted on filling its positions with none but the best material, often allowing them to remain vacant rather than appoint undesirable or even fairly good men. The selections have been made by competitive Civil Service examinations; this is not always the quickest or most advantageous way of selecting professional men, especially when the demand is greater than the supply, but it guards successfully against political influence or favoritism. The Civil Service Commission has co-operated with the Bureau in maintaining a high standard in the scientific qualifications of its personnel. With the exceptions of the leaders in the principal lines of the Bureau's work, the policy has been to appoint graduates of first-class scientific or technical colleges to the lower grades of assistantships, advancing them to the higher grades as they become proficient and vacancies occur. At entrance they are allowed to select the line of work in which they desire to specialize, and every opportunity is given them for development.

Necessarily, the first work organized by the Bureau was that pertaining to the fundamental standards and precision measurements in mass, length, capacity, heat, light, and electricity. The importance of such work is too well recognized for comment, but its character and the apparatus employed can hardly be appreciated by those who have not been brought in touch with it. Consider, for example, the construction of a copy of the standard of length, and the work involved in subdividing it to the ultimate divisions of a micrometer, or the construction of its multiples as used in base measuring apparatus, steel tapes, and other engineering standards, or the testing of various instruments for measuring temperatures from that of solid hydrogen to the highest temperatures that it is possible to produce. And yet, these are but examples that have their counterpart in almost every field of physical measurement.

The work of the Bureau is organized at present in seven divisions, each covering a more or less distinct branch and in charge of one or more experts aided by a corps of scientific and technical assistants. They are, as follows: (1) weights and measures; (2) electricity; (3) heat, thermometry, and pyrometry; (4) light and optical instruments; (5) chemistry; (6) engineering instruments; and, (7) testing and investigation of materials.

The division of weights and measures is devoted to the comparison of standards of length, mass, and volume with the official standards of the United States, all of which are in the custody of the Bureau. These measures are submitted by the Government Departments, by State and city inspectors of weights and measures, by manufacturers, by scientific and technical institutions, and by individuals. In cases where there are no local facilities the Bureau tests and seals commercial weights and measures, provided they conform with certain essential requirements as to construction. This division tests all kinds of instruments for measuring length, mass, or capacity, also hydrometers and barometers, and it is preparing to take up the testing of chronometers, watches and other time-measuring apparatus. It also gathers information as to the laws and usage of local and foreign weights and measures, and when such information is sufficiently important it is published.

A meeting of the State sealers of weights and measures is held at the Bureau annually for the purpose of discussing the means for securing uniform laws and inspection of commercial weights and measures throughout the United States.

It must not be supposed that these divisions are devoted entirely to comparisons and tests; the greater part of their efforts are expended in developing methods of measurement, making investigations, and the determination of such properties of materials as may come within their scope.

The electrical division covers several very important branches, involving many problems difficult of solution and an extensive equipment. Under resistance and electromotive force are classed the construction and verification of resistance standards and standards of electromotive force, together with the various instruments of precision for measuring these quantities. Under inductance and capacity are found the investigation of the methods of measuring inductance and capacity, the construction and testing of the Bureau's standards, the testing of capacities and inductances for the public, and the verification of the apparatus used in connection with these measurements. The investigation and testing of instruments for measuring electric current, voltage, and power (both direct and alternating) and the testing of laboratory and commercial instruments designed for such measurements is also included in the work of the electrical division. It includes, also, magnetism. Instruments and methods for testing the permeability and hysteresis of specimens of iron have been developed.

The section of photometry comprises the testing of incandescent lamp standards for candle power and distribution of light, the testing of lamps as to life, candle power, and efficiency, and the study of special problems in photometry. An equipment for life tests has been installed for the testing of lamps purchased by the Departments of the Government and for seasoning standards.

The photometric work has recently been extended to include gas and other illuminants.

The division of heat, thermometry, and pyrometry is devoted to the testing of thermometers of all kinds, the various forms of pyrometers for the measurement of high temperatures, the determination of calorific values of fuels, and investigations bearing on the establishment and control of the temperature standards of the Bureau. Information is furnished, upon request, as to methods of temperature measurement, thermal constants, specifications for thermometers, etc. An intercomparison of the primary standard mercurial thermometers of the Bureau in the interval 0°–100° Centigrade, in a specially designed comparator, has been made. A number of platinum resistance thermometers, together with the necessary apparatus for their use, have been designed and constructed, to be used in connection with the establishment of the standard scale of temperature. An investigation of the methods of measurement of high temperatures by means of the light and heat emitted by incandescent bodies, with a view to their application in the laboratory and in the industries, has recently been made.

The great importance in many industrial processes of an accurate knowledge and control of the temperatures at which the operations are carried out is well known. The representatives of many manufacturing plants have visited the Bureau with a view to studying the pyrometers in use in its laboratories, and consulting its experts concerning the methods of temperature measurement. At the request of the refrigerating engineers, the Bureau is engaged upon the determination of the specific heat of calcium chloride brine, which illustrates one class of problems this section is called upon to solve.

While the work of the division of optics is chiefly related to the determination of physical laws and constants, considerable testing has been done, especially in connection with polariscopic apparatus and standards. The spectroscopic work has been confined to the determination of the laws and conditions governing the production of pure spectra, with a view to their application in spectroscopic methods, the determination of standard wave lengths, and their use in optical methods of measurement.

The analytical work of the division of chemistry is confined as far as possible to the solution of problems which are important to definite interests or a large number of individuals. Specific analyses are made for the Departments of the Government, and sometimes for the public in cases of dispute, but it is not the desire of the Bureau to enter the field covered by commercial chemists. This division is working upon the standards of purity for chemical reagents. Good progress has been made in securing the co-operation of chemical manufacturers and in the development of methods of testing for impurities in reagents, especially those found in the common acids and alkalies. Samples of a few important materials have been carefully analyzed, with a view to their distribution when necessary for the purpose of checking methods of analysis used in the scientific work in the industries.

For several years the American Foundrymen's Association had prepared and distributed samples of standard irons. By an arrangement with that Association this work has been transferred to the Bureau of Standards which will in the future have charge of the preparation and distribution of such samples. Similar arrangements have been completed with the American Steel Manufacturers' Association as to the preparation of standard samples of steels of the three types—bessemer, basic open-hearth, and acid open-hearth—which have been analyzed and are ready for distribution.

The determination of the ratio between the atomic weights of oxygen and hydrogen and work upon the atomic weight of chlorine are in progress, and illustrate one class of investigations that it is proposed to take up in the chemistry division.

The relation of the chemical work to that of other sections of the Bureau is exceedingly important. Scarcely a problem can be taken up concerning the construction of standards or properties of materials that does not involve chemical preparations, chemical analysis, or the co-operation and advice of expert chemists. The entire work of the Bureau has been greatly strengthened and its efficiency increased by the chemical division.

It has been impossible thus far to assign to the testing and investigating of engineering instruments the space, equipment, and assistance commensurate with their importance. However, the Bureau is in a position to test standard water meters, gas meters, speed indicators, pressure gauges, anemometers, indicator springs, and many varieties of testing machines; it is carrying on investigations relating to the behavior of such instruments under varying conditions, the improvement of their accuracy when desirable, and encouraging their use. It co-operates with municipal authorities in the establishment of their testing plants, verifies their standards, and advises the officials directly in charge of such work.

The testing and investigation of materials depends to such a large extent upon standards of measurement, measuring instruments, power, mechanical equipment, physical and chemical experts that the Bureau has striven to provide these necessary and indispensable facilities before undertaking the work in connection with materials; nevertheless, the demand for it has been so great, especially on the part of the Departments of the Government, that the Bureau was compelled to take it up in a very limited way almost at the beginning. By the testing of materials is not meant the mere resistance tests that can be done in commercial laboratories, but a study of their physical properties with a view to improving the conditions under which they are used, tested, or purchased. Materials are not tested to ascertain whether or not they comply with specifications, except in cases of dispute, or for the Government. There is a decided tendency throughout all of the Departments of the Government to purchase materials in accordance with properly prepared specifications and to make such tests as are necessary to insure that they are complied with. The Bureau of Standards is assisting in every way possible not only by the prescribing and making of tests but in the preparation and standardizing of specifications. The making of these tests for the Government suggests many important problems which when solved will benefit all testing laboratories.

It is the desire to co-operate with laboratories engaged in commercial testing, since it is not the plan of the Bureau to enter that field, but rather to supplement their work. As in the other divisions of the Bureau, manufacturers and others engaged or interested in the testing of materials are free to consult with the experts of the Bureau, and the results of investigations will be made public.

The following are a few samples of the investigations that have been made or are in progress, and are selected to illustrate that the Bureau is endeavoring to organize this work upon a broader and higher plane than is generally understood by the testing of materials: an investigation of the present methods of testing lubricants with a view to determining the relation between the chemical and physical properties of lubricants and their value for specific purposes; the development of physical and chemical tests of glue; the development of methods for the physical and chemical testing of paper, including an investigation of the elements governing the change of dimensions of paper used in printing; the electrical properties of paper have been determined with a view to determining that best suited for the construction of telephone cables; a large amount of paper has been tested for the Government to ascertain whether or not it complies with the specifications upon which it was purchased; the electrical and thermal conductivity of metals and graphite have been determined; an investigation was made to determine the best paraffine to be used in the electrical condensers; and the Bureau is frequently called upon to determine the electrical and magnetic properties of materials. The importance of this work is such that Congress will be asked at the coming session to provide and equip a separate building for it.

The general equipment of the Bureau includes besides the apparatus for heat, light, and power, that necessary for the generation of electricity in the various forms for power or experimental purposes; for the production of high and low temperatures; high and low pressures; for the distribution of steam, gas, compressed air and vacuum, and cold brine to the different laboratories, a detailed description of which would extend this paper beyond reasonable limits.

An instrument shop equipped with suitable machinery and provided with expert mechanicians is an essential feature of any laboratory; this is especially true in institutions where precise measurements and original investigation constitute the greater part of the work. The shop of the Bureau is equipped with modern machinery, each machine separately driven by an electric motor. It is both an instrument shop and a machine shop capable of handling a wide range of work.

Manufacturing concerns and engineers solve great problems by the association of experts. In like manner the different sections of the Bureau co-operate and assist one another. For example, the specialist engaged in the development of methods of testing, or who is making investigations in connection with materials, has at his hands the best facilities for the measurement of length, mass, time, and temperature, and can readily consult with the corresponding experts as well as with the chemist. The advantages to be gained by this association of specialists can only be appreciated by those who have wasted valuable time calibrating or testing instruments which were only incidental to the problem in hand. The aim of the Bureau is not only to provide good standards but to develop better methods of measurement and to assist the public in every way possible toward the introduction of such methods.

The laboratories of the Bureau are always open to manufacturers, scientists, and others who desire information or instruction as to methods of measurements, physical constants, or of the properties of materials. The Bureau receives daily many requests for information of this character, and it is rapidly becoming one of the most important parts of its work.

The relation of the Bureau to the manufacture of scientific instruments and measuring apparatus is very close and important. It is co-operating with the makers of such apparatus in every way possible; they visit the Bureau from time to time for suggestions and advice, and are regularly submitting apparatus to the Bureau for testing and investigation. The time is not far distant when our makers of scientific apparatus will be supplying not only the home demand but foreign markets.

The results of the scientific investigations undertaken by the Bureau are published from time to time in the form of bulletins. These are distributed to libraries, educational institutions, scientific and engineering institutions and societies. Reprints are published of each article that appears in the bulletin; these are distributed to such individuals as may be directly interested in them.

In conclusion, I would state that the Bureau desires to co-operate with the American Society for Testing Materials in every way possible.

DISCUSSION.

Mr. Skinner. MR. C. E. SKINNER.—It was my good fortune last year to visit not only the Bureau of Standards at Washington, but some of the similar institutions on the other side of the water, including the National Physical Laboratory of England, the German National Laboratory and a number of laboratories of manufacturing concerns, and it was with increasing pride in our own institution, which has just been so well described by Dr. Stratton, that I saw these other places. They have had a long start in the matter of time over our Bureau of Standards, but I feel that the work undertaken here is on a scale and covering ground that is equal to the work undertaken by any of the foreign laboratories. It seems to me that the Bureau of Standards at Washington ought to be a sort of court of final resort for testing and testing methods for the Society and I make this as a suggestion, for the consideration of the Society.

The Chairman. THE CHAIRMAN (Mr. Mansfield Merriman).—At the beginning of the paper, and again at the close, a remark was made which indicates that this Bureau is conducted from the point of view of the physicist, the units to be standardized being those of length, time, mass and angle. Now everybody connected with this Society knows that a unit of much importance to engineers is that of force; because otherwise we would not be able to test materials. Since this Bureau is about to take up the subject of testing, I presume that it will also undertake the standardization of the units of force.

Mr. Stratton. MR. S. W. STRATTON.—That is cared for in the Section of Weights and Measures. It comes up in several cases among which is the testing of barometers and the testing of instruments for measuring force. I should like to say in response to Mr. Skinner's remarks that the Bureau will be pleased to co-operate with the Society in assisting to carry out any experiments they may devise and that may properly come within the scope of its functions, and I think the Bureau can receive a great deal of assistance from the members of this Society.

MR. EDGAR MARBURG.—The suggestion of co-operation of the Society with the Bureau of Standards, which Mr. Skinner made in written form about a year ago, impressed me favorably at the time, and it led directly to the invitation that was extended to Dr. Stratton last year to present a paper descriptive of the methods and aims of the Bureau. In order that the suggestion, which seems so promising, may not be lost sight of, it would seem desirable to refer the matter to the Executive Committee for consideration. **Mr. Marburg.**

MR. SKINNER.—I desire to put that in the form of a motion. **Mr. Skinner.**

[The motion was seconded and carried.]

THE STRUCTURAL MATERIALS TESTING LABORATORIES, U. S. GEOLOGICAL SURVEY, ST. LOUIS, MO., PROGRESS DURING FISCAL YEAR ENDING JUNE 1, 1907.

By Richard L. Humphrey.

The paper presented by the writer at the 1905 meeting of the Society described the inauguration of the model Cement Testing Laboratory at the Louisiana Purchase Exposition and its development into the Structural Materials Testing Laboratories conducted under the auspices of the United States Geological Survey. In the paper presented at the 1906 meeting the condition of the laboratories at that time, and the plans for the past year were set forth. It is the purpose of this paper to outline very briefly the present equipment, the work accomplished and the plans for future work.

The Structural Materials Testing Laboratories are divided into sections under the following captions:

Executive.
Editorial.
Computing.
Field.
Constituent Materials.
Block.
Beam.
Fire Tests.
Tension, Shear and Compression.
Permeability and Waterproofing.
Columns.
Floor Slabs.
Chemical Laboratories.
Photographic.

These laboratories are located in Forrest Park, St. Louis, Mo., and are housed in the following buildings:

In Fig. 1 is shown a general view of the laboratories. The low building in the right foreground was built at the time of the Exposition by the Association of American Portland Cement Manufacturers. The center pavilion, 30 feet square, is used by the Constituent Materials Division; the pavilion on the right is used as an office, while that on the left is used by the Park Commission of St. Louis, to whom, at the close of the Exposition, the entire building was presented, and by whose courtesy the government is now using a portion of it.

Of the two large buildings in the background, that on the right is a building 60 x 100 ft. used during the Exposition as a metal pavilion, and now used by the Beam, Tension, Shear and Compression, Columns, and Permeability Divisions. Considerable alterations were necessary to put this building into proper condition, a ceiling was built at a 12-foot elevation, making available a second story the full size of the building.

The large steel skeleton building at the left was used during the Exposition as a foundry building and had a corrugated iron roof and walls of wire netting. It is now used to house the Building Block, Constituent Materials, and Chemical Laboratories Sections. It contains thirty bins, each of one-car capacity, for storing material, a work shop containing machine lathe, drill and grinder, a blacksmith shop and the power equipment for operating the laboratories.

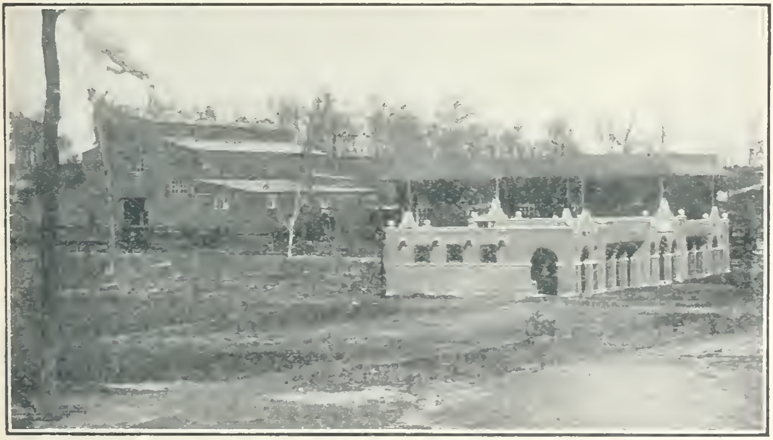

FIG. 1.—General View of Laboratories.

There is also a small building used by the Computing and Drafting Sections and the South Dakota Building used by the Editorial and Executive Sections.

CONSTITUENT MATERIALS SECTIONS.

The constituent materials of concrete and mortar are investigated in this Section for the purpose of determining their suitability for use in mortar and concrete. Samples of sand and stone are sent in by the geologist in the field and are investigated for the percentage of voids, absorption of water, granularmetric composition, specific gravity, and percentage of silt. Frequently, check samples of the materials used in the Beam and Block Divisions are likewise examined.

2- and 6-in. cubes, cylinders 16 in. long and 8 in. diameter, the standard tension briquettes, beams 13 in. long and 1 in. in cross section, and cylinders 6 in. diameter, are moulded from mortar made from the sands and stones. The 2- and 6-in. cubes are tested for compressive strength only, while the modulus of elasticity is determined on the cylinders of 8 in. diameter and the shearing strength on the cylinders of 6 in. diameter. Two sizes of the stones are used, crusher-run and then one-quarter inch. The screenings are used in the small cubes, the tension briquettes and the small beams, while the large material is made up into the large cubes and the cylinders. A separate series of briquettes, small cubes and beams is made of the material screened to one size, the 30–40 sieves used for the sand and the 10–20 for the stone. This one-sized material is used in the proportions of 1 to 3, while all other mortar is mixed in the two proportions of 1 to 3 and 1 to 4. The crusher-run stone is made into a concrete of theoretical proportions and of 1–2–4. Another series of 1–3–5 mixtures is being added. The cement used throughout these tests is a thorough mixture of a number of brands. Fifty barrels, each from ten different plants, were mixed and hermetically sealed in galvanized iron cans of about eight hundred pounds capacity.

The test pieces are broken at 7-, 28-, 90-, 180-, and 360-day periods, and the small ones are stored for twenty-four hours in the moist closet and the balance of the time in running water kept at a temperature of 70° F. The large cubes and cylinders are stored in a steam room and kept covered with wet burlap. Three test pieces are broken at each age.

In order that a check may be had upon the quality of the cement entering each test piece, a parallel series of neat cement tests accompanies each mortar test, the neat tests pieces being made up at the same time and by the same operator as the mortar test pieces. The cement is investigated according to the methods proposed by the Committee on Uniform Methods of the American

Society of Civil Engineers. In making tests on mortar to investigate the quality of the cement Ottawa sand is used.

Up to the first of the year the following materials have been investigated:

71 samples of stone.
3 samples of slag.
25 samples of gravel.
45 samples of sand.
12 samples of cinders.
225 samples of cement.

One end of the main laboratory of the Constituent Materials Division is used for moulding, storing and testing of the small mortar and cement test pieces, and the testing of the concrete cubes and cylinders; while the moulding and storing of the cubes and cylinders and the various tests upon the constituent materials, such as the percentage of voids, granularmetric analysis, weight per cubic foot, specific gravity, etc., are made in the old foundry building.

BLOCK SECTIONS.

A very complete series of tests on building blocks has been started. The series now in hand consists of moulding mortar blocks using the standard cement and Meremac River sand with six different types of block machines and using three consistencies, dry, medium and wet, and mixing in three proportions, 1 to 3, 1 to 5 and 1 to 8.

Cylinders 8 in. diameter and 16 in. long are made from each batch in order to determine the crushing strength and the modulus of elasticity of the mortar in each case. The blocks are stored under different conditions in order to determine the effect of different methods of storage. Some are kept under wet burlap, others are kept wet by simply sprinkling, and a third lot are stored in a steam room. They are investigated as to their fire-resisting qualities, transverse and crushing strength. To date some five hundred blocks have been fired at the Underwriters' Laboratories in Chicago and then tested for transverse and crushing strength at the Armour Institute. About three hundred blocks have been tested for crushing and transverse strength before being fired. In the fire tests the blocks are tested both with and without the subsequent application of water. The blocks fired are 60 days old, while the other blocks are tested for transverse and compressive strength at 30, 90, 180, and 360 days.

The blocks are moulded in the same manner by the same men, out of identical materials in a number of different types of block machines, and are cured in various ways. Some 2,000 blocks have so far been made, and about the same number tested. Transverse tests are made and the two portions remaining are tested for compressive strength. Two car loads of blocks have been shipped to the Underwriters' Laboratories in Chicago, and there tested in the furnace shown in Fig. 2. In addition to fire tests upon a large number of concrete building blocks made upon different machines in different proportions and different consistencies, a series of tests have been made upon brick, terra-cotta, limestone, granite, sandstone, tile, marble, sand,

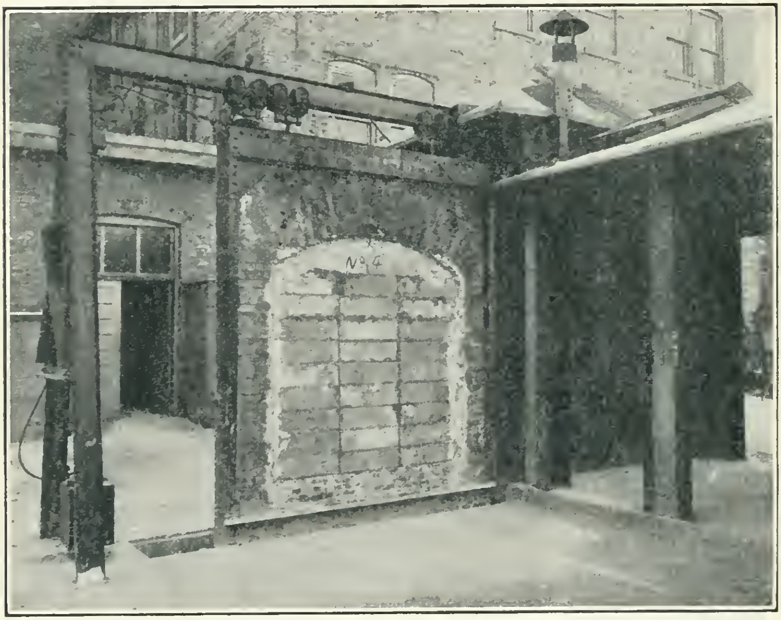

FIG. 2.—Furnace for Testing Blocks.

lime, brick, etc. A few tests were made on a panel composed of a combination of granite, limestone, marble, sandstone, etc., placed side by side and tested under exactly the same conditions.

BEAM SECTION.

The schedule of investigations outlined for this division would probably require ten years for completion. The series now in hand comprises the moulding and testing of some 600 beams, the same number of 6-in. cubes and 8-in. cylinders, and about 100 bond test-pieces. This series is sub-divided into sub-series, the first comprising unreinforced beams composed of the standard cement, Meremac River sand and four different aggregates, gravel, cinders, limestone and granite. The proportions are 1–2–4 by loose volume. Thirty-six beams are made of each large aggregate; twelve of a dry, twelve of a medium and twelve of a wet consistency. Three of each are tested at 28, 90, 180 and 360 days. All the large aggregate is material passing a one-inch screen and held on a one-quarter-inch screen. A cube and a cylinder are made at the same time and of the same material as in each beam. The beams are 11 in. deep, 8 in. wide, 13 ft. long, tested with a span of 12 ft. It will be seen that in this series there are two variables only at each age, the coarse aggregate and the consistency.

The second sub-series consists of cylinders only, made of the four aggregates and the three consistencies but mixed in theoretical proportions. The variables in this sub-series are the aggregate consistency and proportion.

The third sub-series consists of reinforced concrete beams using a medium consistency, the four aggregates and one-half-inch round steel bars. The number of bars to a beam will range from two up to eight, giving percentages of steel to concrete from one-half to two. One set of twelve bond test pieces has been made for each aggregate. The variables in this series are the aggregate and the percentage of steel.

The fourth sub-series consists of limestone, concrete beams of medium consistency only, but the bars vary from one-quarter up to one and one-quarter inches in diameter, making the percentage of steel and the diameter of steel the variables.

A coupon from every bar of steel is tested for elastic limit, elongation and ultimate strength, and every tenth bar for modulus of elasticity. The loads are applied at the third points, and the deformation of the upper and lower fibers, the deflection and the slip of rods are measured by specially constructed instruments. Steel moulds are used for making beams. All test pieces are stored in a steam room and kept covered with wet burlap. The cylinders are measured for modulus of elasticity and crushing strength, and the cubes for crushing strength alone. In this first series the rods are laid flat without stirrups or bending.

In the series of beams moulded during the year plain round medium steel bars only were used. The large aggregate, the consistency, the percentage of steel, and the size of the bars were varied. The tests were so grouped that not more than two variables occurred in any one sub-series. The proposed beam tests comprise a great variety of different sorts of beams arranged in groups. Plans have been made for testing about 1,000 beams arranged in 18 groups. In one of these groups the beams will be tested at the early ages of 2, 7, and 14 days; in another group the variables will be the proportions (1–4–8, 1–3–6 and 1–1½–3), the aggregate (gravel and limestone), and the percentage of reinforcement, using one size of round rock only. The expectation is that with one of the percentages for each proportion, the compressive strength of the concrete will be developed. Another group will be reinforced with high elastic limit steel. One group will consist of beams of various lengths, in another group diagonal reinforcement will be used. Various typical types of deformed bars will be used in one group, and stirrups in another. One group of tests will be made for the purpose of comparing the results obtained by beams moulded in the steel moulds and those moulded in wooden moulds. A rather interesting group of beams will be made in wooden moulds and in steel moulds by a gang of workmen obtained from a contractor engaged in concrete construction work in the city, and will parallel a group of beams made at the same time out of the same materials by the government men. In the Beam Division are a 100,000-pound three-screw testing machine, a 200,000-pound four-screw testing machine, and a 200,000-pound three-screw machine. They are all equipped with wings of sufficient length to accommodate 20-foot beams. There is being installed a 600,000-pound machine capable of testing 24-foot beams and columns of 30-foot length.

Fig. 3 is a view of the storage room, showing the over-head trolleys running upon the lower flanges of steel I beams and the chain blocks which are used for handling the beams. The beams are made in moulds composed of steel channels. They are allowed to remain undisturbed on the moulding floor, resting upon the bottom channel, until they are sufficiently strong to be moved into the storage room.

During the past year over 650 beams, 650 cubes, 900 cylinders and 200 bond test pieces were moulded; and 325 beams, 325 cubes, 400 cylinders, 50 bond test pieces were tested. Also about 3,000 pieces of steel were tested.

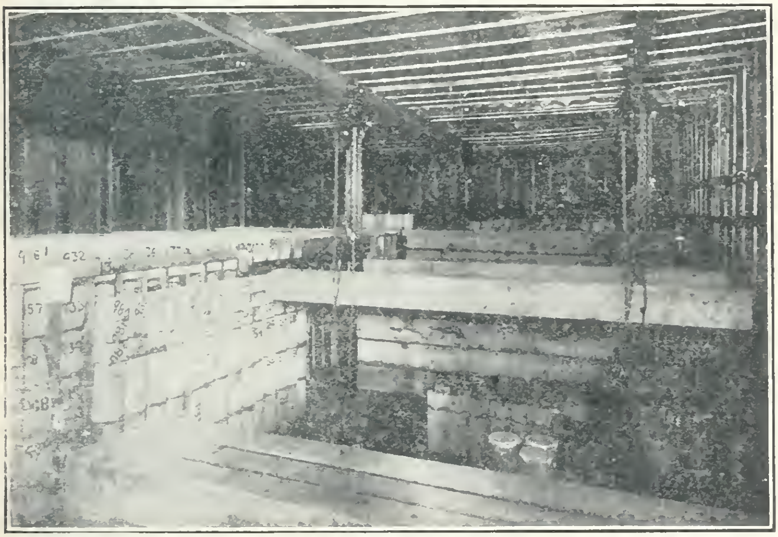

FIG. 3.—Storage Room.

TENSION, SHEAR AND COMPRESSION SECTION.

In this Section the coefficient of elasticity in tension and compression and the strength in shear is determined. The modulus in tension is determined on test pieces 12 in. in section and with a gauge length of 5 feet and of compression on a 16-inch cylinder 8 in. in diameter.

In Fig. 4 is shown a test of the shearing strength of concrete. The apparatus is arranged so that 2-, 4-, 6-, 8-, or 10-in. sections may be sheared from a cylinder 6 in. in diameter. These shear tests parallel the beam tests. The same material that is used in the beams being moulded into cylinders in order that the shearing strength of the material may be determined. The load is applied from the moving head of the machine to the cutting tool through a spherical bearing block.

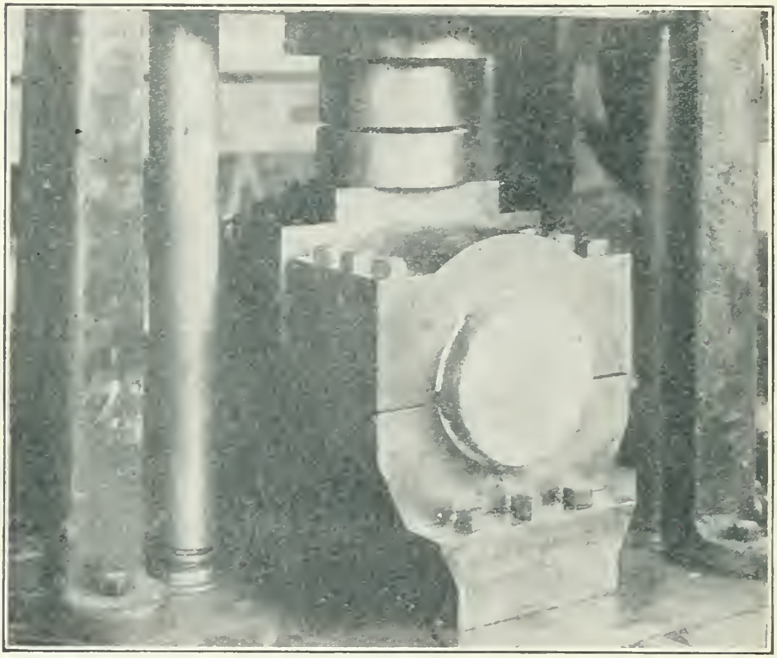

FIG. 4.—Testing in Shear.

PERMEABILITY AND WATERPROOFING SECTION.

Fig. 5 shows an apparatus in use for investigating the permeability of mortars and concretes. Disks seven inches in diameter, of various thicknesses, are moulded in iron rings and bolted in the castings shown in the illustration. They are then coupled to the piping and the air compressed in the large tank by an air compressor in another part of the building forces the water through the disk of concrete under any pressure desired. The copper cylinder hanging below the disk catches the water that passes through, the weight of which may be determined by lowering the

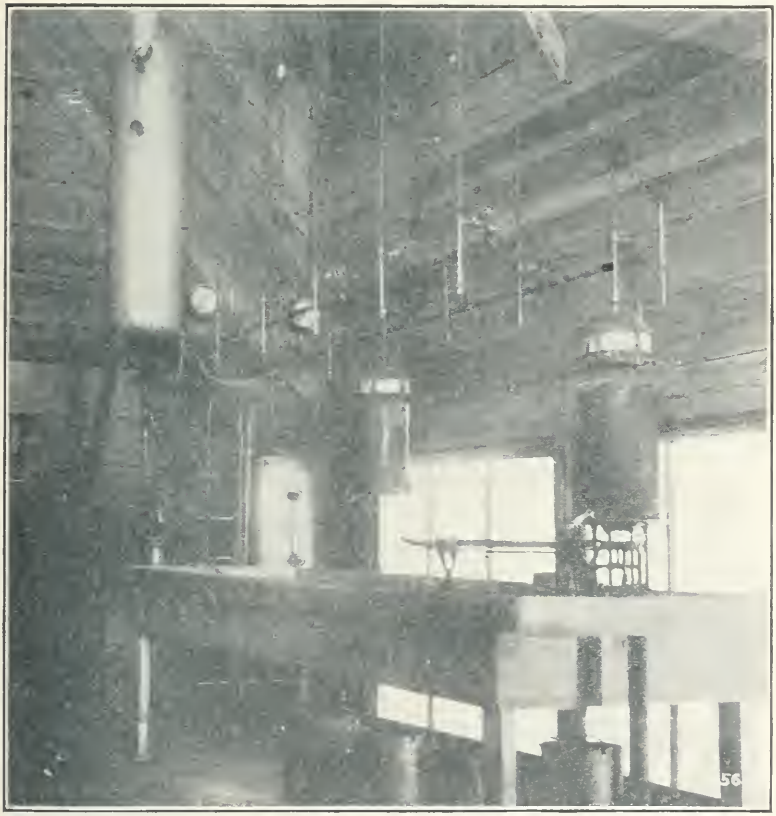

FIG. 5.—Permeability Apparatus.

cylinder upon the scale pan. Plain mortars and concretes and those treated with a great variety of waterproofing compounds, both those which are incorporated in the concrete and those which are applied as a surface coating, are being tested. These compounds are purchased in the open market. About 550 of these test pieces have been made up and are being tested at different ages.

COLUMN SECTION.

Upon the installation of the 600,000-pound testing machine an elaborate series of tests will be started. The first schedule provides for 255 columns. These are grouped, as were the beams, in such a way that not more than two or three variables will exist in any one group. The series will be started by a test of unreinforced mortar columns, both round and square, of 10, 15 and 20 ft. lengths and different proportions. This will be followed by the reinforced columns with longitudinal reinforcement only, lateral reinforcement only, and a combination of the two. A variable in this group will be the elastic limit of the steel.

FLOOR SLAB SECTION.

Tests are soon to be started on 20 x 20 ft. and 16 x 16 ft. floor slabs, plain and reinforced, flat and arched. One group of tests will be upon reinforced slabs supported at the four corners only, another upon slabs supported by beams on two sides, another upon slabs supported on all sides, and still another upon slabs supported on all sides and by an intermediate beam framing.

CHEMICAL LABORATORIES SECTION.

In the Chemical Laboratories Section all the material used in the Constituent Materials Section is chemically analyzed, including the silt obtained from the stones and cement. All the steel used in the reinforcement is chemically analyzed. In addition to this work, samples of cement and cement-making materials are analyzed for the reclamation service. A special series of tests to determine the best method of making specific gravity tests on cement is being carried on.

To the first of the year silt from 32 samples of gravel, 50 of cinders, 142 of stone and 30 of slag have been analyzed, together with 220 samples of cement.

A petrographic sub-division of this Section is about to be inaugurated. Sections of stone, hardened cement and mortar will be made and photographed. This division will also have charge of cutting cubes from blocks of stone which are sent in by the field division from the quarries from which the crushed material is obtained. These cubes will be tested for crushing strength and absorption.

PHOTOGRAPHIC SECTION.

The photographer employed makes photographs of each beam when being tested in order to show the position and appearances of the early cracks, and also the manner of ultimate failure.

FIELD SECTION.

A geologist visits various centers of building activity, inspects quarries or other sources of supplies of the sands and stones used for making mortar and concrete in these centers, and sends samples to the Constituent Materials Section for investigation.

COMPUTING AND EDITORIAL SECTIONS.

The results obtained in all the Sections are sent to the Computing Section where they are thoroughly computed and tabulated. All records are kept by a very thorough and complete card filing system, and the time occupied by each man in making all classes of tests is recorded, so that at any moment the cost of making any test can be ascertained and at the same time a check kept upon the variation of cost from week to week.

The force consists of about sixty-five men and is well organized. The work is under the supervision of a consulting expert, and the details of the work looked after by an assistant engineer in general charge with an assistant engineer in charge of each section.

In all the concrete tests the greatest care is used in having the materials of uniform quality so that when these qualities are once determined they may be considered consistent quantities in comparing one set of tests with another. The cement used is a thorough mixture of a large number of standard brands from all over the country, that now in use being a mixture of 18 brands. This mixture is stored in galvanized iron cans of about 800 pounds capacity with lids so arranged that they may be sealed until ready for use. The cement in each can is tested immediately after being mixed and when used. The same sand is used throughout all the concretes. It is a sand donated to the laboratories in large quantities by a company operating on the Meremac River near St. Louis.

All the steel used in the reinforcement is selected by representatives of the laboratories who make tests upon the steel at the steel works before the bars are accepted.

The three consistencies used in the first series of beam and block tests, termed "wet," "medium" and "dry," were carefully determined in advance of the tests. The sand and large aggregates are tested each morning to determine the percentage of moisture contained in them, in order that the proper amount of water, in addition to that already contained in the material, may be added to bring the concrete to the required consistency.

All concrete is mixed in a machine mixer of the rotating cubical type. Three of these mixers are in use, one by the Beam Division, one by the Constituent Materials Division and one by the Building Block Division.

Since the beginning of the work at the Exposition over 35,000 investigations have been made.

SOME AVOIDABLE CAUSES OF VARIATION IN CEMENT TESTING.

By Ernest B. McCready.

The continued wonderful growth of the cement industry adds increasing emphasis to the necessity for a uniform standard of tests and a more general adherence thereto. The first has already been provided through the efforts of this Society and its co-workers. The realization of the latter is, in some respects, still a long way off.

Uniformity in the grade and quality of the cement itself will never be possible. There will always be grades in cement just as there are grades in pig iron. The fact is not yet generally recognized that cement is not, like sugar and salt, a standard commodity of uniform value so long as it is unadulterated with some foreign material. Cement is more nearly comparable to the bread or cake or confection (to carry out the figure) and its quality depends as much on the kind and character of the raw materials as on the skill of the cook. What we need to know now is not so much whether the food is fit to eat but rather which food is best suited to our needs. Our tests must do more than differentiate between that which is merely good and any that may be positively bad. Our aim for the future must be to give a correct value to the *grade* of material we are testing. This can only be done by treating each sample as every other sample is treated, so far as practicable, making the necessary variations only according to fixed rules.

The valuable work done by this Society in formulating, adopting and recommending for general use uniform methods of procedure in carrying out the more common tests on cement, have accomplished much towards this end. But while progress has undoubtedly been made in this direction, very much more remains to be done. Many differences of method still exist and many testers cannot or will not recognize the necessity for a change.

In the conduct of a commercial laboratory probably more than in any other, these facts and the desirability of uniform standards are constantly being emphasized. The manufacturer has to contend with the notions and peculiarities of various engineers and consumers. The commercial laboratory has to do not only with these but also with the idiosyncracies of the manufacturer as well. The problem of harmonizing these discordant elements is the one that must be faced and solved first of all. It is the purpose of this paper to point out only a few sources of difference and contention (or at least of misunderstanding) which might easily be avoided by the general acceptance of a common ground on which all parties are *willing* to stand.

It is probable that the question of tensile strength has to do, in some form, with more disputes concerning cements than any other test. Such differences are usually ascribed to that convenient scapegoat, the "personal equation," which, although it is often the source of decided differences, is by no means the most troublesome factor with which we have to deal at the present time. Many trials have shown that men working side by side do get closely agreeing results when the work is done with reasonable care and intelligence. It is equally true that results from different laboratories often disagree more than would seem to be possible on the same cement. A study of the reasons for such differences and the conditions which produce them is interesting.

There are probably not more than half a dozen laboratories in which there is any earnest, careful effort to carry out every operation in accordance with the directions adopted and promulgated by this Society. On the other hand, there are laboratories where absolutely no effort is made to conform to these requirements. And it is a fact that there are cement testers in competent charge who have never read over or even heard of these Standard Methods.

The reason for this state of affairs is not hard to find. The fact that any other brand of cement had reached a given strength in somebody's laboratory tests makes it incumbent upon the sale agents of each new brand to show that their cement can do as well or even a little better. When some engineer reports that he has made some tests and that he gets the best results on a cement whose strength is limited at seven days, and always specifies such cement, it immediately becomes the fashion for engineers, without further investigation, to write in their specifications a limit to the tensile strength or else a specified minimum rate at which the cement shall harden or both. Again, it is "up to" the manufacturer. He must prove by his own tests at least, that his cement will do as it is told if he expects to bid under these specifications. So, nothing matters but results. No mention is made of the methods or conditions under which the tests are made. Hence we have this state of affairs; in the laboratories of various manufacturers we find that "normal consistency," or its equivalent, means anything from a paste so wet that it can be stirred up (gauged?) and filled into the molds with a spoon or knife in less than a minute, to a paste almost or quite as dry as is commonly used with the Boehme hammer and which is compacted in the molds with wooden tampers or with an iron form and a hammer.

It is not surprising, then, to find that an application of the Standard Methods in treating these different brands results, on the one hand, in higher short time tests than those obtained by the manufacturer and consequently a smaller gain in strength as measured by percentage, while the same relative treatment applied to another brand gives results considerably lower than the strength claimed for it.

It is sometimes argued that it is not fair to treat all brands alike, and the reasons advanced seem plausible; *but*, the user makes no difference in his treatment of different brands and indeed it would be impracticable to follow out the minute changes necessary to allow for the peculiarities of various brands. We must not lose sight of the fact that the object of testing cement is to get information as to its comparative behavior under uniform conditions. We all know that our test methods are arbitrary. This has been said so often that it is becoming trite. But until the recognized standard of measurement is changed by common consent to something better, it surely behooves us all to "measure by the stick."

In many laboratories the effect of temperature on the results is practically ignored and in only a few is *any* attempt made to keep the temperature uniform. Any room that can be spared in any part of a building is often considered good enough for a laboratory. Not long since the tests on the cement for an important work were carried on by the inspector in a small closet without ventilation and necessitating the use of artificial light continually. It is not necessary to add that the cement was often found to be quick-setting. In a cold laboratory, on the other hand, an actually quick-setting tendency, which might lead to serious trouble on the work, is likely to be overlooked.

Briquettes of different ages are often stored in different rooms. Frequently only those to be broken at seven and twenty-eight days are kept in a heated room, the longer time briquettes being stored in a cellar or other convenient place, in water which is seldom or never renewed and taken therefrom at a temperature of perhaps 40° F. or less in winter time and immediately broken. The results are recorded without comment and at some later time are serenely compared and averaged with others broken, perhaps, in midsummer under exactly opposite conditions, and the *cement* gets all the credit or blame, as the case may be, according to the showing.

Occasionally laboratories built for the special purpose, light frame structures, perhaps, while otherwise well equipped and well suited for the purpose, are turned into veritable ovens in summer time by a low tin or other flat roof.

The writer has several times been called upon to determine the reason for abnormal differences in the results of different laboratories. In one instance a chronic case of lack of gain or else retrogression at twenty-eight days was traced to a laboratory temperature which so hastened the hardening of the test pieces that practically the full ultimate tensile strength was developed at seven days or less, while the continued high temperature of 90° to 95° really produced before the end of twenty-eight days much the same effect as an accelerated test would have shown in a few hours. The hydration of any small quantity of uncombined lime present was hastened, causing a falling off in strength, which normally might not have appeared until a year or more later.

In another case in mind, a finely ground, slow setting cement was rendered so much slower by a laboratory temperature of 60° F. and cold gauge water that the 24-hour briquettes showed only about half the strength required by specification; and after six days immersion in water at 60° or less the strength was still below specification requirements, both neat and sand. The cement itself was perfectly normal except in setting time as just noted which was about seven hours under normal conditions.

These cases serve to illustrate the extremes and all possible variations between that are constantly being brought to the attention of the manufacturer and the commercial laboratory.

There is much more to be standardized than the mere manual procedure of testing. Engineers need to recognize the fact that it is unfair to pick out what they conceive to be the "good" points of several different brands and apply them as a measure to all brands which they may use. They should remember that high neat tests do not usually mean correspondingly high sand tests; that fine grinding is not often consistent with high neat tests; that because one laboratory reports a certain percentage gain on one brand is no reason why anyone should require the same gain from some other brand and especially without inquiry as to the method of manufacture and testing which produced these results.

There is obviously a limit to the tensile strength of Portland cement and the nearer this limit is approached at seven days, the less possibility remains for much gain thereafter. And no tests have ever shown that this fact of itself renders a cement less desirable than one whose seven-day strength is so low that it can gain largely up to twenty-eight days or longer. For most modern work the former would seem to be the more desirable cement. Any marked retrogression in either case is due largely if not wholly to details in manufacture. In fact it is the writer's experience that nearly all cements which at any time fall off to or below seven-day strength are those which are known to be unsound when tested or not properly burned, and this occurs most frequently with low-pulling, light-burned cements.

There is much room for education on the part of the cement user. He needs to know, first of all, what he really wants in a cement,—that is what properties are of special value in his work. With this knowledge will come a better realization of the necessity not only for uniform methods but what is more to the point,—uniform tests. When he realizes that because one brand does not harden quite so rapidly as another, it is not necessarily inferior for the average piece of work; and that the cement which fails to gain 12 or 15 per cent. over 900 pounds from seven to twenty-eight days is not likely to suffer by comparison with average cements in any other way; that when properly made and seasoned these cements are equally good for most ordinary work (although one or the other may be superior for some special work); when these facts are generally understood and appreciated there will be no reason for a manufacturer to modify his test methods so as to make a given showing,—to obtain predetermined results,—and uniform tests will be advanced a long way and the manufacturer will be the first to hail such a condition.

[For Discussion of this paper, see page 360.

SOME PROBLEMS OF A CEMENT INSPECTING LABORATORY.

By R. S. Greenman.

In considering this topic, this paper will discuss the problems of the laboratory which inspects cement proposed for use on work, rather than those of the laboratories of the cement mills or of those laboratories where cement is tested theoretically or experimentally. Of course there are kindred ties between these laboratories, and all may be working under the same general methods, and yet between them there may be a considerable difference. These problems are not extraordinary ones but are such as one in charge of an inspecting laboratory often has to meet and which it is necessary for him to use time, experience and tact in trying to solve.

The work of most mill laboratories is usually that of testing only the product of the mill, and in a certain sense it becomes strictly routine with only occasionally a problem for consideration; the problems of theories and of experiments interest other laboratory workers; but a laboratory which inspects and tests a great number of samples representing large quantities of cement of many different brands meets conditions which are perplexing and ofttimes are far from easy solution. Possibly some of these can not be called problems and yet they are so out of routine work that they have to have special attention.

Theoretically it would seem that there should be no need for inspecting laboratories, for do not the cement mills test and examine all cement made and shipped? And yet, what inspecting laboratory does not find that large numbers of samples of poor cement are submitted for tests. Just why it is so is not readily explained. It must be that sometimes the mill laboratory must make a mistake, for it would be uncharitable to call the presence of poor cement on the market the result of deliberate intention. So, in considering this subject, we will have to consider the inspecting laboratory as being a check on the mill laboratory; and although both may be working under similar methods, it is possible to find many differences in their results. The very fact that such differences do occur is the cause of the greatest annoyance to the inspecting laboratory. There seems to be too general suspicion among representatives of the cement companies that a rejection of a lot of cement by an inspecting laboratory means one of two things:—either that the tests are crude and made by ignorant persons who do not understand the first principles of cement testing, or that there is some hidden reason for making trouble for the company manufacturing the cement.

It is perfectly natural for the cement company, when their tests show the cement to be all right, to feel some resentment at a rejection of their product, but as long as a human being is liable to err, as long as there are no methods of testing that have absolutely no faults or weak spots, and just as long as inspecting laboratories find poor cement, just so long should the question first be raised "Where is the mistake, in our laboratory or in the inspecting laboratory?" Both laboratories have a chance of making the error. The inspecting laboratory, before rejecting, should make check tests; the cement's representatives, before criticizing, should learn the real conditions of the case and after obtaining such knowledge should then be fair in their judgment. An illustration would perhaps help bring out the thought. All cement to be used on state work of any nature in the State of New York has to be tested in the laboratory of the State Engineer and Surveyor. A shipment of cement for use on some state buildings was rejected. The representatives of the cement insisted that the cement was good and had been unfairly tested by the state's testers; they threatened to compel, by means of the courts, the use of the cement. The whole case was the cause of a considerable controversy and finally check tests were made by the president of the cement company on one hand and by the writer on the other. The writer's tests were found to give true results. The outcome of the whole case was that the cement company found a deliberate error in their own laboratory, apologies were made and the cement removed from the work. It should be stated that this feeling of suspicion, or opposition, is generally between those laboratories of both classes which have never had occasion to come into a position of mutual understanding; and that the tendency seems to be toward recognizing the inspecting laboratory as having the best of motives, methods, and men.

Some of the differences between these laboratories are already receiving due consideration from the best sources. Take for example the matter of making the tests for fineness. Uniform methods and uniform requirements have amounted to nothing when it was impossible to get uniform sieves. One of the hardest problems has been to secure a sieve of a standard mesh and wire. As an example to illustrate this point:—Some time ago, some cement on a large piece of work was running very coarse. The first time this occurred the cement was accepted with a protest to the manufacturers that the cement would be rejected if it continued coarse. Well, it did, and a car-lot was rejected; and the result was that a representative of the company visited the inspecting laboratory and protested against their sieves; he also brought his own standard sieve. Tests showed a difference in amount passing the No. 100 sieves of over five per cent. Sieves of both parties had been bought as being standard. The manufacturer of the cement had a sieve which upon examination showed 92 meshes per linear inch while the inspecting laboratory sieve was 102 meshes per linear inch. This experience is not different from that many have had, but it emphasizes the need of getting together. This problem of sieves, however, is being solved since it has become possible through the Committee on Technical Research of the Association of American Portland Cement Manufacturers to secure sieves that are truly standard.

Another problem of the inspecting laboratory is in regard to tests for set. It seems that quite frequently a cement, that in tests made at the mill will show it to be a normal setting cement, will, when sampled upon the work and tested in the laboratory, show it to be a quick setting cement. While it is known that temperature affects the setting of cement, still tests made at different temperatures with cement, air and water, all at the same temperature, will frequently show the flash set. A cement that will take an initial set in three minutes and a hard set in five minutes has something radically wrong; it is not a matter of temperature, or of consistency, as is usually claimed; but rather, we usually find it to lack a proper amount of added gypsum. The cement has, however, passed the mill laboratory tests and there is, therefore, a resulting controversy between the two parties.

Tests for tensile strength we all know will vary in the same and in different laboratories, so differences of opinion as to strength should be dealt with by having a re-test made in the inspecting laboratory with representatives of the manufacturers of the cement to watch and inspect the making of the tests. It becomes one of the problems, however, of the inspecting laboratory how to treat cement fairly from the point of view of both the user and manufacturer and yet not use too great force in molding the briquette. A good square test for strength without aiming to obtain abnormal results should be the intent of the inspecting laboratory. How to do this is the problem. We have prescribed a standard method of mixing the mortar and of molding the briquette; and although the intent may be there to follow minutely the standard method, it often happens that a cement which is just near the required strength can be made to pass or fail because of the personal equation in the work of the operator. It is this condition which causes trouble; and, as has been suggested, here is the opportunity for a mutual test and no misunderstanding.

It is also a live question as to what an inspecting laboratory should do in regard to the kind of sand to use in making standard tests. Of course we know that the "Ottawa" sand has been recommended; we also know that comparatively few laboratories are using it. It must also be considered that the "Ottawa" sand makes a denser and stronger briquette; and that because it does do so, it is necessary, before its use can be adopted, to have a large series of tests with all brands of cements in order that the inspecting laboratory may obtain the relative value of the sands under its own tests. By using the same requirements with the new sand as with the old, there would frequently pass a cement that would have failed with the quartz sand. So, in other words, it is necessary to raise the requirements, but just how much is fair is the question.

"Green" or "uncured" cement is also a condition that causes difference of opinion; but while the difference is being discussed, the cement may have improved, so this is not a very serious problem although it often produces much annoyance to the contractors because of the delay.

The inspecting laboratory, too, has the same problem to deal with that mill representatives have in regard to the ignorance of users of cement who often have crude ideas of cement testing and who make crude or field tests of cement. These persons, sometimes they may be engineers, will not know the characteristics of the cement they are using and will imagine something wrong with good cement. Their crude tests will perhaps confirm their ideas.

Proper sampling of cement is also hard to obtain. Recently we received a lot of twelve samples, supposedly taken from every tenth barrel of a lot of 120 barrels. The cement had a "flash" set and was rejected. A duplicate lot of twelve samples, taken from the same lot of cement, were slow setting and considerably darker in color than the first samples. Upon inquiry as to what this difference in color might indicate as to the sampling, the reply contained the suggestion—"The cement left over in the laboratory from the testing of the original samples had, through exposure to the atmosphere, undoubtedly 'bleached out'".

It might be said that a proper interpretation of specifications for cement is a serious problem. Shall the interpretation be literal or liberal? It stands to reason that, if, for example, tests of cement show the cement to be good in all the requirements except fineness, the cement could be used without harm to the work. On the other hand, if the use of this cement is permitted, how is it going to be possible to strictly draw a line in other particulars?

The inspecting laboratory is in existence to protect the interests of the user of cement and all the questions before it have to be considered from the point of view of such user and all other views must be secondary, but should be treated with the idea of having a "square deal" for all.

[For Discussion of this paper, see page 360.]

DISCUSSION.*

Mr. McCready. MR. E. B. McCREADY.—There is much that I would like to say in this discussion, because the subject is such a fruitful one; it has so much of interest to those engaged every day in this particular line of work. I shall confine myself, however, to but one or two points which appeal most strongly to me.

But first I would like to say that I do not want Mr. Greenman to rest under the impression, which his parenthetical remarks on my paper would seem to indicate, that I was making reflections on the private laboratory of the consumer, especially. The moral of my remarks was pointed quite as much at the laboratory of the manufacturer. It was simply "for him whom the shoe fits". I know from personal experience and my own observation that there are imperfections on both sides.

The manufacturer "lives, moves and has his being" on a plane different and distinct from that which bounds the horizon of the consumer. The two are sometimes very near, sometimes widely separated. Each has studied, experimented and become more or less familiar with conditions as they have appeared from his point of view. It should be the aim of each, always to be able to put himself in the other's place; to have a better appreciation and realization of the problems and conditions which confront the other.

As a matter of fact, the attainment of this broad view is largely impossible to more than a few. The peculiar problems of different manufacturers, the varied conditions which confront the engineer and contractor, would require too much time and study for the average individual. Those of us, however, who confine our labors to the testing and investigation of materials cannot be too conversant with both phases of this subject. And this applies not only to the chiefs or heads of testing laboratories; if anything, it applies with greater emphasis to every other member of the staff because the chief often depends almost wholly on the reports of his assistants. **Mr. McCready.**

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* This Discussion covers the two preceding papers.—ED.

Take, for example, the sampler. No part of the testing is of greater importance than the sampling, and yet I am tempted to say that no one knows less about his business than the average cement sampler. The laboratory of a well-known railroad company sent out no less than four different men in succession in one season to sample cement in the Lehigh Valley district and not one of them had any previous experience and little, if any, instruction as to his duties.

I happened to be, recently, at the office of one of the large cement companies, in conversation with the shipping clerk, when in rushed a young man—a boy he was, really, but half way through his teens—and demanded, breathlessly, "Where is that cement for——? I have only ten minutes to catch the train back." I was interested enough to see the incident through. The boy was shown to a pile of about 2,000 barrels on the floor of a stock house, when he hastily took a box from under his arm, opened it and scooped up enough cement from one spot, at the edge of that pile, to fill it and away he went. That sample was supposed to represent the 2,000 barrels. It is unnecessary to enlarge upon the worthlessness of such a test. The customer who ordered and paid for that test paid for something which he did not get. And not only that; such methods are likely to injure both the consumer and the manufacturer. Unfortunately, the attitude of the manufacturer toward the inspector or tester is only too often one of suspicion; and incidents such as those just mentioned do not tend to lessen this feeling. On the other hand the consumer often seems to go on the assumption that the manufacturer is always a knave who is constantly on the watch for a chance to outwit him. Such instances are usually those in which there is a large contract and the consumer maintains his own testing laboratory. The friction which not infrequently results is nearly always the direct result of the ignorance or prejudice of the inspector sent to the works.

The lesson is plain. None but fully experienced men should be given charge of any important work of a testing laboratory. The commercial laboratory, especially, should not be a training school for young engineers or cement testers. Too much depends upon the acceptance or rejection of a lot of cement; the safety of

Mr. McCready. the work, on the one hand, and the great expense caused by unwarranted or unnecessary rejection on the other.

In regard to the subject of Multiple Tests: I am sure that our President did not have in mind cement or cement testing when he discussed this subject last evening. Certainly the safety of both manufacturer and consumer depends upon a multiplicity of tests on cement. The changes which are constantly going on in cement often necessitate repeated tests when the material is not used promptly. It is not enough to have the cement tested when it is made. It should be tested again when it is shipped. Even then it may have changed before it reaches the work so as to be unfit for use. For example, at certain seasons of the year it is necessary to test some cements daily for setting-time; and here experience and good judgment are especially needful. Not all quick-setting cements should necessarily be condemned. A recent shipment to one of our large railroads was rejected by the company's tester as being quick-setting. An investigation by the manufacturer's representative showed that the material had become quicker setting although not extremely so, and he reported that the cement would probably be all right if unloaded and stored for a few days in a cooler place than the freight car. This was done at the manufacturer's risk and the material, after being retested, was accepted.

Mr. Price. MR. C. E. PRICE.—Just a word in regard to the resampling of cement. In the past two years I have had considerable experience in the retesting of green cement; and it has been the contention of the manufacturer that if a bin of cement was resampled at the end of 28 days that it wouldn't be as "hot," as they termed it, and would show better results. I have been called upon many times to resample and test bins of cement which failed on the first test, and in most cases have been obliged to turn them down on the second test. Had this cement been bagged and stored in a well-aired storehouse for a period of six months and then tested, there is no question but what it would meet the requirements of our specification, providing, however, that it was a first-class sound Portland cement.

The principal difficulty experienced has been the failure of cement to meet the requirements as to the gain in the neat and mortar tensile tests, this is probably due to the fact that the cement has not had proper time in which to season.

THE SPECIFIC GRAVITY OF PORTLAND CEMENT.

BY RICHARD K. MEADE AND LESTER C. HAWK.

In the report of Committee C "On Standard Specifications for Cement" made to the Society in 1904, under the heading "General Observations," appeared the following paragraph:

> "Specific Gravity is useful in detecting adulteration and underburning. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications."

Shortly after the publication of this report one of the writers was approached by a city engineer who stated that he did not care for a certain cement because on two occasions where he had obtained samples of this brand they had proved to be of a low specific gravity and he believed that this cement was not as hard burned as other brands. This remark started the writers on a series of experiments which have extended over a period of nearly three years to determine the causes which lead to low specific gravity in Portland cement and the actual value of the test. In the meantime the Committee on Technical Research of the Association of American Cement Manufacturers took up the subject and their two reports will be found in several technical journals. Butler, an English chemist, also made experiments along the same line which he described in the proceedings of the Institute of Civil Engineers.

Naturally the first condition to receive attention was the degree of burning. This was done in the following manner: A kiln was detected "cold" as we call it, or not hot enough to properly burn the mixture, and from this kiln twelve samples were drawn as the kiln was heated up to slightly above normal temperature. From these samples, four were selected as representing (1) very soft underburned clinker, (2) slightly underburned clinker, (3) normally burned clinker and (4) very hard burned clinker. These clinkers were then rapidly ground to pass a standard 100-mesh sieve and the specific gravity at once taken. The need of haste was occasioned by the fact that the underburned clinker rapidly absorbs carbon dioxide and water from the air, which lowers its specific gravity. The specific gravity of the three samples was found to be:

1. Very soft underburned clinker			3.208
2. Slightly	"	"	3.222
3. Normally burned		"	3.214
4. Very hard burned		"	3.234

The ground clinker was also mixed with 2 per cent. plaster of paris, and made into pats which were subjected to the steam test. At the end of two hours the pat made from the very soft underburned clinker had entirely disintegrated. At the end of five hours the pat from the slightly underburned clinker had become checked and partially disintegrated. The other two pats stood the steam test satisfactorily; and also five hours longer, in boiling water, had no effect upon them.

In this experiment we have four samples of clinker all burned by the same kiln from the same lot of raw material, one of which was so poor as to fail after only a short period in steam, while two were sufficiently well burned to stand perfectly the steam and boiling tests, yet the extreme difference in specific gravity between the four was only 0.026. We have frequently taken the specific gravity of underburned clinker and in no case have we ever found it below that of the standard specifications. The experiments made by the members of the American Cement Manufacturers' Association, conducted at six different mills, gave an average of 3.14 for the specific gravity of the underburned cements and 3.18 for that of the hard burned ones. A sample of raw material being ignited merely sufficiently to drive off the carbon dioxide without any appreciable clinkering, had a specific gravity of 2.996. It would therefore be possible to make a mixture of half and half of this partially burned raw material and well burned Portland cement clinker which would pass standard specifications, so far as specific gravity is concerned.

The effect of adulteration can of course be calculated accurately. The substances most available for adulteration of Portland cements in this country are natural cement, raw material or limestone and slag. Rosendale or natural cement has probably been used more than any of the others. Its specific gravity ranges between 2.8 and 3.1. In detecting a mixture of Rosendale cement and Portland cement the value of the test will depend entirely upon the specific gravity of the Rosendale. In the case of a natural cement with a specific gravity of 2.9 it would, of course, be possible to mix as much as 1 part Rosendale to 2 parts Portland, while with natural cements of higher density more Rosendale could be used.

The raw material or cement rock of the Lehigh district has a specific gravity of about 2.7, hence very little of it could be used without lowering the specific gravity appreciably. Its dark color would also cause its presence to be suspected and chemical analysis would readily detect it. Limestones average in specific gravity about 2.8, that only about 20 per cent. of the mixture could be used without lowering the specific gravity below that called for by the standard specifications. In the case of blast furnace slag, the density of which is somewhere around 3.0, large quantities could be used without detection by the specific gravity test. The writers recently had a sample of basic slag containing 36 per cent. silica, of which the specific gravity was 3.05. A mixture of 1 part of this slag to 1 part of Portland had a density of 3.12.

It would seem therefore that while the test would be of value in detecting additions of limestone or cement rock, it is by no means an infallible one or even a reliable one for detecting admixture of Rosendale or slag.

It has long been known that the storage of cement caused a lowering of its specific gravity. This is easily explained by the fact that cements on exposure to air absorb carbon dioxide and water, forming calcium carbonate and calcium hydroxide. The former has a density of 2.70 and the latter of 2.08. The effect of storage on cement is shown by the following:

Sample No.	Specific Gravity.				
	1	2	3	4	5
When made	3.19	3.21	3.16	3.15	3.20
After 28 days	3.11	3.12	3.10	3.09	3.08
After 6 months	3.08	3.04	3.08	3.03	3.04

A sample of cement had a specific gravity of 3.21 when fresh and after lying in a warehouse three years had a specific gravity of only 3.02. Its properties at the end of that period were excellent and the only noticeable change in its condition was that it was slightly caked.

It is now generally conceded that the seasoning of cement is an advantage, and many tests by various operators show that cement shows its best strength after a storage of from three to six months. Yet it is probable that cement which has been stored this length of time will have a specific gravity of less than 3.10. If the cement does not absorb some carbon dioxide and water no benefits will be derived from seasoning, and if it does absorb them the specific gravity is bound to be lowered thereby. The absorption of 3 per cent. carbon dioxide and water is sufficient to lower the specific gravity of cement below 3.10. An underburned cement which failed when freshly made to stand a five hours' steam test without complete disintegration had a specific gravity of 3.185. After being seasoned one month it stood five hours' steam and boiling tests perfectly, but its specific gravity had fallen to only 3.082.

With the problem of manufacturing large quantities of Portland cement economically, to meet the increased demands for building materials, has come the practice of storing cement clinker. This can be done out of doors at a much smaller cost than it is possible to store cement in a warehouse. This clinker also grinds much easier and allows the manufacturer to give the engineer a better product for the same money than could be originally done. It has been found, however, that such clinker made a cement of lower specific gravity than would have been the case if the clinker had been ground fresh from the kilns. Otherwise the cement is excellent. For example, a sample of clinker fresh from the coolers gave a specific gravity of 3.18; after being exposed out of doors for one month the specific gravity fell to 3.04, and after two months' exposure to 2.96. The cement made from the exposed clinker had a neat strength of 677 pounds at the end of seven days and 765 pounds at the end of twenty-eight days, and a sand strength of 330 pounds in seven days and 394 pounds in twenty-eight days.

It will be seen therefore that seasoning or storage of the cement has a much greater effect upon the specific gravity than underburning or adulteration.

It has been proposed in cases where the specific gravity of cement falls below the limit prescribed by the specifications that the sample should be ignited and the specific gravity of the ignited sample taken. We have made a large number of determinations of specific gravity upon seasoned cements from which we find that practically all samples of cement when ignited give a specific gravity of between 3.15 and 3.22 and that most of them give around 3.20. This conclusion was also reached by the Committee on Technical Research of the Association of American Portland Cement Manufacturers, and by Butler.

Upon igniting a mixture of 40 per cent. Rosendale and 60 per cent. Portland cement having a specific gravity of 2.985 before ignition we were surprised to obtain a specific gravity of 3.20. This result was checked with practically the same result. A mixture of 40 per cent. cement rock and 60 per cent. Portland cement which had a specific gravity of 2.95, gave after ignition 3.20. This would prove that the ignition of the cement and determination of the specific gravity of the ignited sample fails to give any indication of adulteration even where this has taken place to a considerable extent.

CONCLUSIONS.

1. The specific gravity test is of no value whatever in detecting underburning, as underburned cement will show a specific gravity much higher than that set by the standard specifications. Underburned cement is readily and promptly detected by the soundness tests, and no others are needed for this purpose.

2. The value of the specific gravity test as an indication of adulteration is much exaggerated. While a large admixture of any light adulterant with the cement would be shown, there is at the same time much slag and also Rosendale cement which could be mixed with cement in large quantities without lowering the specific gravity below the limit of our standard specifications.

3. Low specific gravity is usually caused by seasoning of the cement or the clinker, either of which improves the product.

4. The proposition to ignite the cement sample which falls below specifications and determine the specific gravity upon the ignited portion is of no value because adulterated cements also have their specific gravity very much raised by such ignition.

5. The requirements for specific gravity should be omitted from the standard specifications, or at least that the clause which infers that low specific gravity is caused by underburning and adulteration should be omitted and that in its place there should be inserted one stating that low specific gravity may, but does not necessarily imply adulteration, as it is in most cases due to seasoning of the cement or storage of the clinker before grinding, both of which are beneficial to the product.

DISCUSSION.

Mr. L. W. Walter.—I don't see any room for adverse criticism of Mr. Meade's paper. It certainly appears especially good. **Mr. Walter.**

I have been making determinations at various times for specific gravity of samples of cement received at the laboratory, and have held those samples and again made the determination at a period of from six to twelve months after the samples were received. I have almost invariably found that the specific gravity of the cement sample, after aging, falls below 3.10, which is the limit recommended in the standard specifications.

While I have not made experiments to determine the effect of adulteration in modifying the specific gravity of cement to the extent that Professor Meade has, I must say that our results indicating the difference in specific gravity due to the aging of cement coincide very closely. Referring to the article in the specifications which states that the specific gravity of Portland cement must not be less than 3.10, and accepting as correct Professor Meade's view that cement after aging is better than the same cement before aging, I would add that in my opinion this article in the specifications should be dispensed with, because if the specifications be adhered to rigidly the cement might be rejected for the reason that it runs low in specific gravity; whereas, the fact that it runs low in specific gravity might indicate, at least, that it is a better cement than it would otherwise be.

Mr. C. E. Price.—Owing to a point brought out in Mr. Meade's paper, that I might not be misunderstood in my former statement regarding retests, I would say that my remarks were confined to a retest at the end of 28 days. The result obtained from tests made on some 25,000 to 30,000 barrels of cement which had been stored in our warehouses from twelve to fifteen months, more than met the requirements of our specification, while most of the cement only barely met the requirements on the usual twenty-eight-day test. **Mr. Price.**

The Chairman. THE CHAIRMAN (Mr. Robert W. Lesley).—The Chair would like to add a rather interesting thing that came to his observation on a recent trip to Europe.

We know, all of us, that the setting time of cement is supposed to be regulated by the plaster. We all know that many years ago various experiments seemed to show that at a certain period which could not always be identified, but depended somewhat upon the material to which plaster was added, that cement that was made slow-setting again became quick-setting. In other words, there was a sort of period of instability where the cement which had been made slow-setting by plaster, and yet had not been made slow-setting by the absorption of moisture and carbonic acid gas (which is the natural way of slowing the set), was in a state of instability, and it suddenly became quick-setting without apparent reason. We have had one or two descriptions of that phenomenon, without the explanation.

In England, in the new works of the Associated Portland Cement Manufacturers, where they are dealing with the most modern works in Europe, they have introduced into all their grinding machinery, tube mills (water or steam) under what is known as Bamber's patent; and they are obtaining not only a very uniform method of rapidly seasoning cement, but a permanent seasoning rather than the temporary seasoning of plaster. It might be interesting for some of those experimenting on that subject to have samples of that cement; and I shall be glad to furnish them, so that they can determine the specific gravity, and ascertain whether the effect is not analogous to leaving Nature do its work.

THE CONTROL OF PHYSICAL TEST RESULTS IN PORTLAND CEMENT.

By W. A. Aiken.

At our 1905 convention the writer submitted tabulations of results in both neat paste and 2:1 standard quartz mortars of various classes of Portland Cement inspected and tested for the Board of Rapid Transit Railroad Commissioners of the City of New York, in connection with a paper on "Low-pulling early-stage Portland Cement vs. the ordinary early-strength-developing product," illustrating our specification requirement of a minimum gain between 7 days and 28 days. The classes referred to included accepted material, rejected material and "turned over" material, this latter being such which on account of high 7 day results seemed unlikely to meet our specifications of a minimum gain. Later there was submitted to the Association of American Portland Cement Manufacturers at their Niagara Falls meeting a paper, wherein the results previously submitted to this Society were differentiated with reference to the lime factors of various classes to establish the influence within very narrow limits of the chemical composition upon the physical results. At this latter date, the following theoretical analysis was submitted for material of the Lehigh cement section, embodying such proportions as are likely to furnish cement to meet our gain requirement and to give best results, particularly in mortars at long-time periods:

Minimum Silica.	Maximum Alumina.	Maximum Iron.	Lime.	Maximum Magnesja.
21.00	9.00	3.25	62.50 to 63.25	3.00

To apply this theoretical analysis to the accepted material on which results were presented to this Society two years ago is the object of the present paper.

The average results, originally given, are as follows:

Tensile Strength in Pounds per Square Inch.

NEAT CEMENT.

24 hrs.	7 days.	28 days.	3 mos.	6 mos.	1 yr.	2 yrs.	3 yrs.
300	689	799	799	799	805	791	759

Gain, 16.0 per cent.

2:1 MORTARS.

24 hrs.	7 days.	28 days.	3 mos.	6 mos.	1 yr.	2 yrs.	3 yrs.
	404	525	568	549	552	523	492

Gain, 30.0 per cent,

AVERAGE CHEMICAL ANALYSIS.

Silica.	Alumina.	Iron.	Lime.	Magnesia.	L. F.	C. I.
20.92	8.53	2.78	63.05	2.38	2.60	1.05

As originally shown, all our accepted cement showing least early strength with corresponding greater gain between the specification periods of 7 and 28 days give best results at 3 years with less retrograde movement at intermediate periods, with analysis agreeing with the theoretical one, later advanced as ideal.

The following tables show the differentiation of all original results on accepted cement into two classes by Silica content above and below 21 per cent., as indicated by the theoretical analysis, each of these being further subdivided according to its Alumina content into 5 classes; viz., less than 7 per cent. Alumina; between 7 and 8 per cent. Alumina; between 8 and 9 per cent. Alumina; between 9 and 10 per cent. Alumina, and over 10 per cent. Alumina.

Silica Over 21 Per Cent.

Silica.	Alumina.	Iron.	Lime.	Magnesia.
22.09	6.74	2.66	62.60	2.19
21.78	7.50	2.66	62.85	2.25
21.48	8.55	2.66	62.92	2.33
21.36	9.20	2.84	62.78	2.37
21.16	10.61	3.00	61.96	2.74

PHYSICAL RESULTS.

Tensile strength in pounds per square inch.

NEAT.

24 hrs.	7 days.	28 days.	3 mos.	6 mos.	1 yr.	2 yrs.	3 yrs.
224	665	779	882	767	766	722	846
262	666	777	808	795	785	747	757
298	672	788	797	798	807	787	775
317	671	788	796	805	801	777	784
277	631	729	708	806	788	788	782

2:1 MORTARS.

7 days.	28 days.	3 mos.	6 mos.	1 yr.	2 yrs.	3 yrs.
366	495	576	553	553	550	503
367	502	534	523	515	489	484
401	525	583	562	543	501	485
410	539	592	581	563	527	482
342	506	532	594	561	532	449

SILICA UNDER 21 PER CENT.

Silica.	Alumina.	Iron.	Lime.	Magnesia.
20.35	6.85 .	3.36	62.62	2.62
20.43	7.54	2.97	63.40	2.53
20.33	8.51	2.74	63.38	2.42
20.40	9.23	2.89	62.91	2.39
20.04	10.47	3.07	62.78	2.30

PHYSICAL RESULTS.

Tensile strength in pounds per square inch.

NEAT.

24 hrs.	7 days.	28 days.	3 mos.	6 mos.	1 yr.	2 yrs.	3 yrs.
286	735	826	809	780	795	...	...
304	704	801	784	778	789	848	...
309	718	834	810	797	810	821	826
312	694	804	818	813	823	807	786
331	631	765	778	792	785	751	748

2:1 MORTARS.

427	537	560	509	482	...	...
416	523	546	513	492	...	...
418	530	561	525	492	494	447
418	537	591	572	539	488	459
398	516	564	547	535	494	448

It is to be noted that the material analyzing Silica over 21 per cent. gives in every case except one, the last class, (and this can be explained by its lower lime content) better gain from 7 days to 28 days, than the corresponding division with Silica lower than 21 per cent. establishing, as far as our gain requirement is concerned, the fixing of the minimum Silica of the theoretical analysis.

It is to be noted irrespective of the absolute Silica requirement that those subdivisions approximating 9.0 per cent. Alumina as a maximum, give better gains at our specification period, seemingly establishing the theoretical Alumina maximum.

In the first three classes where the Alumina corresponds to the theoretical analysis, the better gains of the Silica content above 21 per cent. in all cases correspond with lime in agreement with this same ideal requirement, establishing similarly the limiting of this element from 62.50 to 63.25, which is further emphasized by the fact that the lime content more positively controls final results in all cases than do the other elements as shown in tests of material with Silica below the theoretical 21 per cent.

It is to be noted in the last subdivision showing abnormally high Alumina that the influence of the theoretical lime content with the lower Silica is marked by much better gain than in the higher Silica subdivision of this higher Alumina material where the lime content falls very much below the theoretical requirement.

Referring to physical results in mortars at later periods, these correspond very closely to the hoped-for results from the low, early-stage strength almost invariably found in the higher Silica material, where the lime and Alumina contents correspond to the theoretical requirements.

The fact that the highest Silica, well above the minimum requirement of the theoretical analysis and the lowest Alumina, very much below the theoretical maximum for that element, with lime content within the theoretical limits give actually best long-time mortar results is interesting and is confirmed by the product of a special mill furnished us for the past year, showing this particular composition.

Further detailed comparisons and examinations might be made but I consider these unnecessary to establish the satisfactory conclusion that the originally advanced theoretical analysis, if complied with, will furnish material in every way satisfactory and likely to give desired results, low early-strength, good gain between 7 days and 28 days, and best long-time results in standard quartz mortars, while similarly proportioned mortars, where a fair natural sand is used would give better results in every way on account of the better grading of the material.

DISCUSSION.

Mr. McCready.

MR. E. B. MCCREADY.—I have been interested in looking over this paper. Results and deductions from a large number of tests, as in this instance, are always interesting. It should be remembered, however, in reading this and similar papers, that conclusions and rules deduced from tests made chiefly or solely on one brand of cement lose much of their apparent value to the profession generally. Rules deduced and applied—as in this instance—may be wholly wrong when applied to another brand of cement; and might, if this fact be overlooked, result in much misunderstanding and injustice. A broad knowledge of the often widely varying conditions at different mills would prevent such misconception, but the average engineer is not a cement expert and cannot have more than a very superficial idea of the processes of manufacture.

It would be exceedingly interesting to have the same work done on a number of different brands of cement, separately, for comparison. As has been suggested before, the question of tensile strength is still a very open one. From a tendency to demand of all cements a gain in strength (neat) of 10, 12 or 15 per cent. between 7 and 28 days, the pendulum is swinging back, so that to-day the sole requirement usually enforced is that the cement shall not retrograde from 7 to 28 days.

With our present knowledge it is doubtful whether we have a right to say that a cement which breaks at 900 pounds in 7 days and loses, say, 5 per cent. at 28 days is inferior to any other because that other does not show a loss until *after* 28 days. All Portland cements do retrograde, sooner or later, to some extent; this much is freely acknowledged by everyone. And all engineers who make long-time tests know that samples making the poorest showing at 28 days as regards percentage gain often give the best results at later periods; and there are numerous records to prove that those cements which, of necessity, because of their composition, give high short-time tests, are, to say the least, not inferior to the

Mr. McCready. low-pulling cements which take much longer to reach their greatest strength.

Some cements show a greater actual strength at every test period than others, regardless of individual percentage gain or loss. We are apt to overlook this fact when talking and thinking percentages. Percentage gain, after all, refers only to the rate at which the cement hardens. What we want and what we use in cement is strength. Five hundred pounds at 7 days and 600 at 28 days means 20 per cent. gain, but you get no more for your money than you would in a cement making 800 pounds at 7 days and 801 at 28 days, and some engineers would think they had less.

As regards the chemical analysis, it would be impossible to make a salable cement at some mills, of the composition suggested in this paper. The nature of the raw material in some localities is such that it is necessary to keep the lime above 63 per cent. Again, there are other mills where approximately the same composition would give very different results in tensile strength.

MR. MCCREADY (by letter).—In reference to the rate of gain, which is the basis of deductions in this and previous papers along this line, it seems to me that the author has overlooked a most important factor. In tests conducted, as are these, at the works, on perfectly fresh cement, a notable percentage of the briquettes made up, taken as a whole, will be made from cement which is not sound to the boiling or steam test. That this is true to a greater or less extent, the records of every mill will show. Of course it "seasons" in a few days and is sound, presumably, when shipped or used, but it is not then the same material which went into the briquettes which are held to represent it.

There is little doubt that "unsoundness" due to imperfect mixing or to coarse grinding of raw material and clinker will have some effect on the strength of the briquette. The effects of ordinary unsoundness as shown by warping and checking in the steam or boiling test never become apparent to the eye in cold water pats or briquettes. The force which operates to cause the swelling and checking in the hot test develops so gradually in the cold that the growing strength of cohesion between the particles easily keeps ahead of it. But this force is there, nevertheless, and its full value is not always developed in a week or a month or a year, witness the fact that test pieces made of unsound cement (which fails to any marked degree in the boiling test) **Mr. McCready.** and kept in cold water, will, if immersed in boiling water for a few hours, swell and check and exhibit the usual signs of unsoundness even after six months, a year or longer (the oldest of such specimens tested in this way by myself have shown this phenomenon).

Here is a condition which may occur and frequently does occur, more often in some brands than in others, which is wholly independent of the chemical composition and of the short-time strength, and which should, it seems to me, be investigated. No cement is perfect as regards the chemical combination of the elements which enter into it; and all cement must, of necessity, contain *some* of the material generally designated as free or uncombined lime,—presumably an oxid of lime which does not react readily with water, either because of its being more or less hard-burned or because, on account of coarse grinding, small particles of the material are protected from the action of water for a time by an outer coating of cement clinker. The length of time required for the hydration of such particles is indefinite and depends on conditions which produce them as before stated. In many cements the amount of such uncombined lime is reduced to a minimum by careful methods of manufacture; but even in these, especially when tested fresh, there are frequent evidences of the presence of such a negative force in the pronounced irregularities in the results of tensile tests.

To sum up, briefly: Any tendency to unsoundness, whether sufficient to become apparent in the boiling test or not, develops, more or less gradually, a disruptive force which is opposed to the cohesive force developed by the normal cement. In all ordinary cases the cohesion or hardening of the cement increases at a greater rate, during the earlier stages, than the opposing force caused by the hydration of the uncombined lime. We have then a case of unbalanced forces. If the latter action be hastened by the application of heat the relation is reversed, there is less increase in strength—perhaps even a loss—and if there is more than a very small quantity of uncombined lime present the test piece is checked, swelled and broken. When the amount of uncombined lime is not enough to cause disruption, the strain exerted simply weakens the specimen so that it is more readily broken in the testing machine.

Mr. McCready. All of these effects except the culmination (checking and disruption) may be observed in the cold water specimens, although the time required is usually very much longer. Occasionally, variations in burning and grinding produce cement in which the effects above mentioned are shown in a falling off in strength from 7 to 28 days. Such samples often make a greater gain than usual thereafter, apparently showing that the negative force had reached its maximum within the earlier period.

The rate at which this disruptive strain increases in different samples under various conditions of burning, grinding and testing, is the kernel of the nut which we ought to crack before placing too much reliance on rules deduced simply from analyses or percentage gain.

LABOR SAVING DEVICES IN A CEMENT LABORATORY.

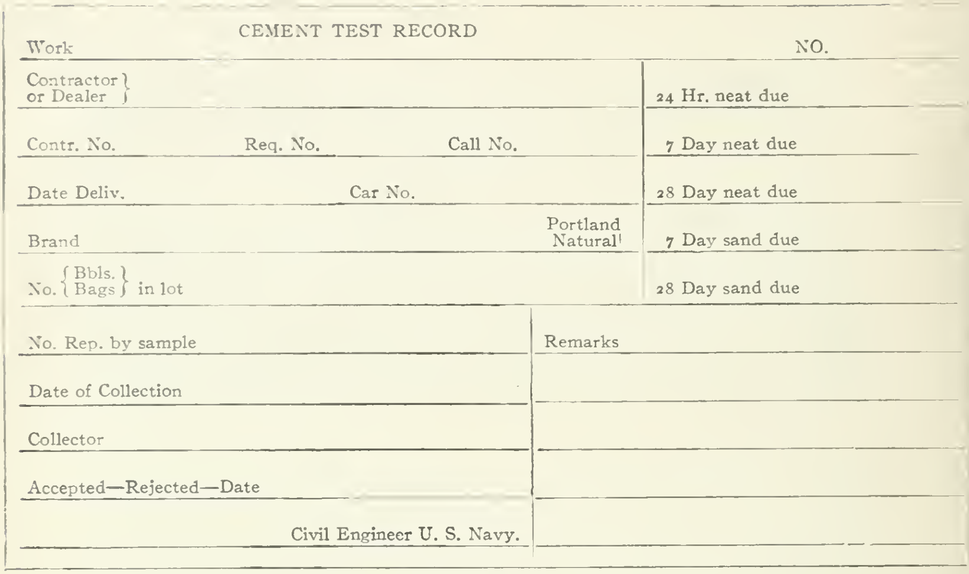
BY R. E. BAKENHUS.

The remodeling of a cement laboratory in preparation for the beginning of extensive public improvements was the occasion for installing devices for the saving of labor with a simultaneous increase of output. Some of the devices were specially designed. As they were subsequently adopted by other laboratories and as interest has been expressed in the laboratory, this brief account has been prepared.

The mixing and sifting arrangements and briquette machine were of the usual modern type. A mixing table of very heavy construction was built, having a polished marble top set on a bed of mortar about 3 inches thick, the mortar being carried in a fixed box or frame, into which the table legs were built. The former galvanized iron briquette storage pans kept filled by a hand watering can and also the wooden shelves upon which they stood were replaced by a tier of long shallow tanks with water spigots over one end and overflows to the sewer at the other, similar to the Philadelphia City tanks. Water may be changed at the expense of only a few seconds of the attendant's time.

The briquettes are not placed directly in the tanks but in galvanized wire desk baskets into which a pane of glass has been laid to serve as a smooth bottom. The baskets may be loaded on the mixing table, a proper grouping being preserved and the test number written on the celluloid tags tied to the basket. The baskets with the briquettes are at the proper time immersed in the tank.

For the keeping of records—an important feature—a special card was devised. See Figs. 1 and 2 for face and reverse sides. All the information with reference to the test appears on the card; the data on the face is filled in when the briquettes are made; the data on the reverse side is filled in as the test progresses. In the upper right hand corner the "due" dates of the tensile tests are placed. As all cards of incompleted tests are filed together the tests due on any day may be readily determined by an examination of the file.



CEMENT TEST RECORD

Work

NO.

Contractor } or Dealer }

24 Hr. neat due

Contr. No. Req. No. Call No.

7 Day neat due

Date Deliv. Car No.

28 Day neat due

Brand Portland Natural

7 Day sand due

No. { Bbls. Bags } in lot

28 Day sand due

No. Rep. by sample

Remarks

Date of Collection

Collector

Accepted—Rejected—Date

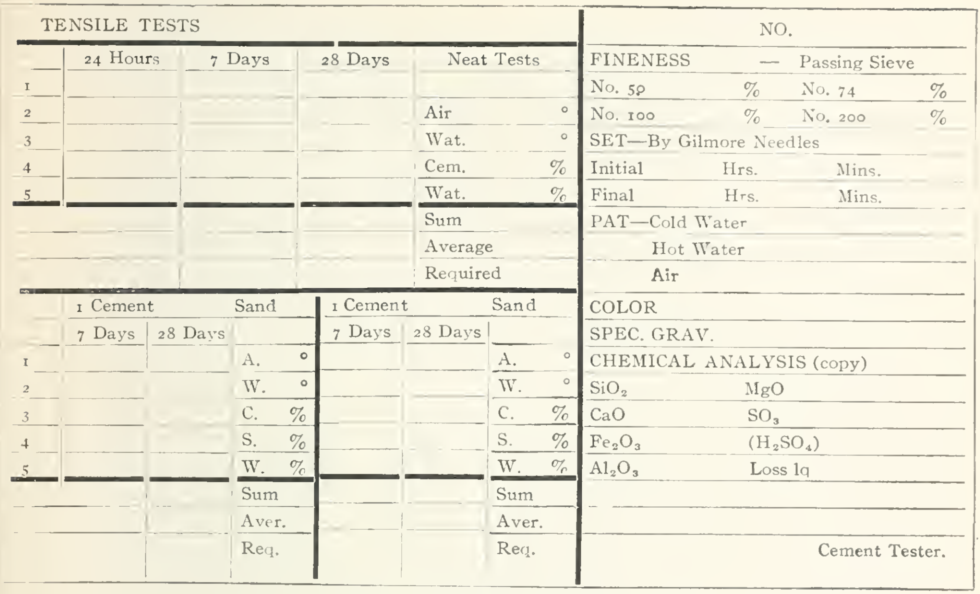
Civil Engineer U. S. Navy.

FIG. 1.—FRONT OF CARD.

The back of the card contains the *original* record of every test except the chemical; even the averaging of the tensile tests appears on the card. No time is lost or errors introduced by copying. The card is more easily handled on the testing table than a book, and, as a whole it forms a complete, compact and original record of all the information concerning the particular test. The omission or failure of a test or any discrepancy can be easily detected, due to the arrangement of the form. Labor is saved and accuracy gained as the recording merely requires the methodical following of a predetermined plan. The card is not copyrighted.

Upon completion of the test the card may be filed with others, either by brand or contract. The tests are best numbered consecutively and the cards then filed by contracts. The numbers may be assigned before collection of sample.

The cement collector is given numbered blank tags which he fills in with data such as brand, car number, date of delivery, name of contractor and other useful information. This tag is tied to the sample delivered in the testing room. The collector fastens small



TENSILE TESTS

	24 Hours	7 Days	28 Days	Neat Tests
1				
2				Air °
3				Wat. °
4				Cem. %
5				Wat. %
				Sum
				Average
				Required

	1 Cement		Sand	1 Cement		Sand
	7 Days	28 Days		7 Days	28 Days	
1			A. °			A. °
2			W. °			W. °
3			C. %			C. %
4			S. %			S. %
5			W. %			W. %
			Sum			Sum
			Aver.			Aver.
			Req.			Req.

NO.
FINENESS — Passing Sieve
No. 50 % No. 74 %
No. 100 % No. 200 %
SET—By Gilmore Needles
Initial Hrs. Mins.
Final Hrs. Mins.
PAT—Cold Water
Hot Water
Air
COLOR
SPEC. GRAV.
CHEMICAL ANALYSIS (copy)
SiO_2 MgO
CaO SO_3
Fe_2O_3 (H_2SO_4)
Al_2O_3 Loss Iq

Cement Tester.

Fig. 2.—Back of Card

tags with sample number to each bag or barrel sampled, showing exactly where he obtained the cement.

The capacity and output of the laboratory referred to was easily doubled and at a saving in expense of operation.

TESTS OF CONCRETE COLUMNS.

By Arthur N. Talbot.

Before taking up a discussion of the recent experiments I desire to modify a statement made in a discussion of this subject at a meeting of the Society a year ago, since the form of the printed discussion may be misleading. The remark was made that in the tests of reinforced concrete columns made at the University of Illinois there was indication that the steel buckled before the ultimate strength of the columns was reached. Further study of the tests shows that the steel did not buckle or reach its elastic limit until after the load taken by the concrete had reached its maximum, although in a few instances the load sustained by the column when the rods buckled, was equal to or a little greater than the load when the concrete was seen to be taking its maximum stress. Fig. 1* gives the stress-deformation diagram for one of the columns. The line marked "Line for steel" represents the stress in the steel as though distributed over the full area of the column, based on the observed deformation in the column and a modulus of elasticity of 30,000,000 pounds per square inch for the steel under the assumption that the concrete and steel act together. The line marked "Line for concrete alone" was found by setting down the line for concrete and steel (i. e., for the column as a whole) an amount equal to that given by the "Line for steel." The line for concrete obtained in this way, corresponds closely with the line obtained in tests of plain concrete columns. This diagram gives a convenient method of comparing the stress taken by the steel with that taken by the concrete, if we assume that the stress in the steel is proportional to the shortening of the column. The ratio between the unit-stress taken by the steel and that taken by the concrete at any stage of the loading of the column, based on the above assumption, for the columns tested, is shown in Fig. 2. The average value for this ratio at the beginning of loading is 13; at three-quarters of the maximum load (corresponding to one-half the ultimate shortening) it becomes 18, and at the maximum load 26. The extreme range of this ratio for the individual columns is considerable. It may be also added that in these tests the strength of unreinforced columns was considerably less than the strength of 12-inch cubes made at the same time. A more complete discussion of these tests may be found in a bulletin of the Engineering Experiment Station of the University of Illinois.

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*Acknowledgment is made to the *Engineering Record* for most of the cuts used in this paper.

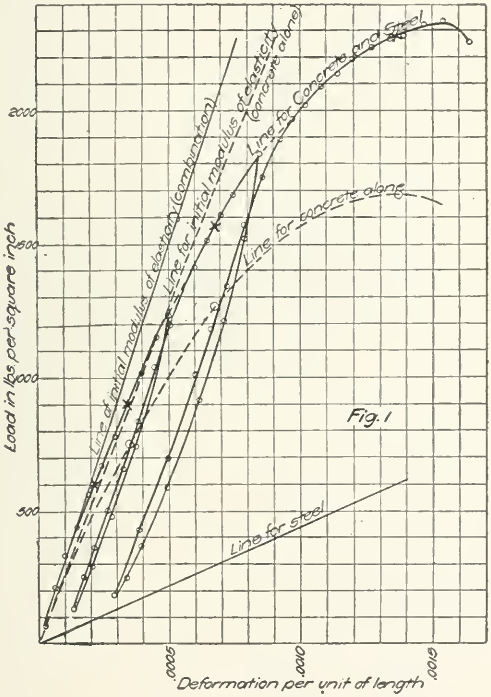


Fig. 1

Passing now to the tests which have recently been made at the University of Illinois, it should be stated that only a summary of the results will be given here and that a more thorough study of the tests will be made later. The tests include three classes of columns: (1) plain or unreinforced concrete columns; (2) columns reinforced with circular hoops or bands; and (3) columns reinforced with wire in the form of spirals or helices.

The concrete used, unless otherwise stated, was composed of one part of Portland cement, two parts of sand, and four parts of broken stone, by loose volume. A detailed description of the materials and of the method of mixing will not be given here. The columns were fabricated in galvanized iron forms. The concrete was a wet mixture, wet enough to allow stirring or churning in the forms. The forms remained in place for ten days. The columns were built on cast iron base plates, and an upper base plate was embedded in plaster of Paris on the top of the column a few days before the test. The average age at test was about 60 days. The columns were circular, 12 inches in diameter and 10 feet long. A few were made 9 inches in diameter. In order not to complicate the analysis of strength, the hoops and spirals were barely covered at the surface of the column, the thickness outside the hooping being generally less than $\frac{1}{4}$ inch. The area of the column was taken to be equal to the area corresponding to the diameter of the hooping. The circular bands used for hoops were 1 inch wide and of three thicknesses, No. 8, No. 12, and No. 16 gage. The yield point of this material was about 48,000 pounds per square inch. The hoops were electric welded. Tests of the hoops usually showed failure outside of the weld. In the few cases where failure occurred at the weld the breaking load was beyond the elastic limit of the steel. Generally the hoops were spaced 2 inches apart, center to center, although in some columns the spacing was 3 and 4 inches. The spirals were No. 7 wire and $\frac{1}{4}$-inch wire. Ordinary black wire and high-carbon steel wire of both sizes were used. Considerable difference was found in the elastic limit of the high-carbon material; the smaller size gave about 60,000 pounds per square inch, and the larger size 110,000 pounds per square inch for the yield point. For the black wire the yield point for the No. 7 was 38,000 pounds per square inch, and for the $\frac{1}{4}$-inch, 54,000

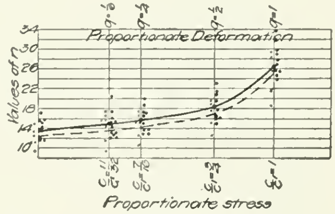


Fig. 2

pounds per square inch. No longitudinal reinforcement was used. The thin longitudinal spacing bars used to hold the hooping in place were not considered in the calculations. In the statement of amount of reinforcement the percentage is based upon the volume of the hooping and the volume of the concrete core; or what is the same thing, upon the area of the hooping considered to be uniformly distributed over the length of the column and the area of the concrete core.

The plain concrete columns gave results similar to those tested a year ago, both in the ultimate strength and in the character of the stress-deformation diagram. The strength of the 1-2-4 columns averaged about 1,620 pounds per square inch, with a range of variation of 30 per cent. on either side of this. The stress-deformation diagrams approximate a parabola, but the total shortening at failure was somewhat less than that given in the 1906 tests. Fig. 3 gives a diagram for one of the columns. An interesting feature of these tests was the determination of the lateral deformation or enlargement of the column. The measurement of this expansion is extremely difficult and this work is of an experimental nature and the results are not to be considered final. Further study of the data will be required to interpret them fully. It seems, however, that the value of Poisson's ratio found from these tests is generally less than that given in text books. This is particularly true for the smaller loads. The ratio increases rather suddenly somewhat before the maximum strength of the column is reached. The line at the left of Fig. 3 gives the amount of the lateral unit-deformation. From a hasty study of the results it would appear that Poisson's ratio averages 0.1, or somewhat more, for the lower loads, and that near the maximum load this ratio rapidly increases to .25 or .3.

Fig. 4 gives the strength of columns made with different mixtures of concrete. The abscissas give the proportion of cement in terms of the weight of the sand and stone used. The results given are the average of from 2 to 5 test columns. The diagram brings out the effect of adding cement in giving strength to concrete columns.

The general phenomena of the tests of hooped columns are as follows: The early part of the test is much the same as for plain concrete columns. At a load equal to that which would cause failure in a plain concrete column or a little above, the concrete over the spacing bars begins to scale, and this is soon followed with a scaling and shelling off of the surface of the column over the hoops everywhere. With added increments of load the amount of shortening increases rapidly and the column expands or bulges laterally correspondingly rapidly. The lateral deflection of the column from a straight line begins to be apparent just before the maximum load carried by the column is reached, and it rapidly increases after the maximum load is passed, forming a curve having the characteristics of the figure shown in textbooks for columns with fixed ends. The columns finally bent out of line, in some cases as much as 4 or 5 inches, the load finally carried being only a small proportion of the maximum.

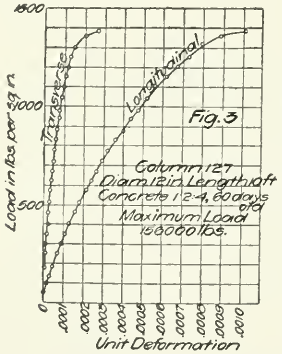


Fig. 3

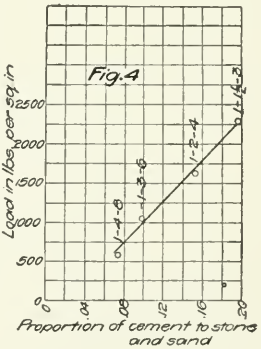
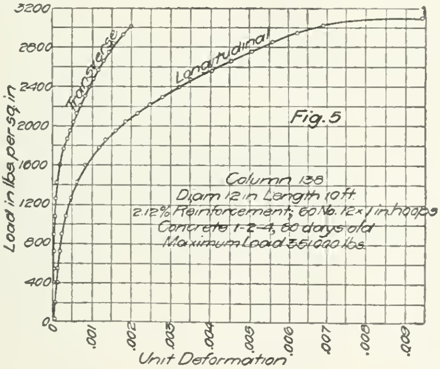


Fig. 4

Fig. 5 shows the stress-deformation diagram for a column reinforced with circular hoops and may be considered to be characteristic. In this and in the other columns the load carried when the column had shortened an amount equal to that which plain columns exhibit at failure corresponded to the maximum load of plain concrete columns. If the line beyond the elbow (approximately straight) is produced to the vertical axis or axis of ordinates, the load there indicated agrees closely with the maximum strength of plain concrete. The diagram indicates that up to the load where a plain concrete column would fail the shortening and the lateral deformation correspond closely with those obtained for plain concrete columns, and but a small stress is developed in the hoops. The line at the left of the figure gives the lateral unit-deformation. Beyond the critical point referred to the longitudinal deformation or shortening increases rapidly with an increase of load and the lateral deformation increases correspondingly. The total amount of shortening is considerable, in this column being nine times as much at the maximum load as may be expected in a plain concrete column at its maximum load. The maximum strength of the columns occurs when the bands have been stretched to their yield-point. Beyond this point the deformation increases rapidly but the load falls off. Fig. 6 gives a view of one of these columns after the outside scale has fallen off and some time after the maximum load has been applied.

Fig. 7 gives the stress-deformation diagram for a column reinforced with high carbon wire. The early part of the diagram is similar to that already described. The total amount of shortening is greater, as may be expected from the higher elastic limit of the reinforcing. The total shortening at the maximum was thirteen times what may be expected in a plain concrete column at the time of failure. The lateral deformation curve shown at the left of the figure cannot be compared with the former one since the instruments were placed on the concrete between the wires and, as would be expected, the lateral swelling at these points is greater than for the reinforcement itself. Fig. 8 gives a view of one of these columns after the maximum load had been applied.



The results indicate that the strength of the columns is dependent upon the strength of the concrete mixture, the amount of the hooping reinforcement, and the yield point of the reinforcing. In other words, the additional strength over that of plain concrete columns is a function of the amount and strength of the reinforcing. In Fig. 9 are plotted the strength of the hooped columns and the amount of hooping. The lower line may be considered to represent the strength of the columns with mild steel hooping. Its equation is $P = 1600 + 65{,}000\,p$, where p is the ratio of the hooping to the concrete core. The upper line is for hooping having a higher

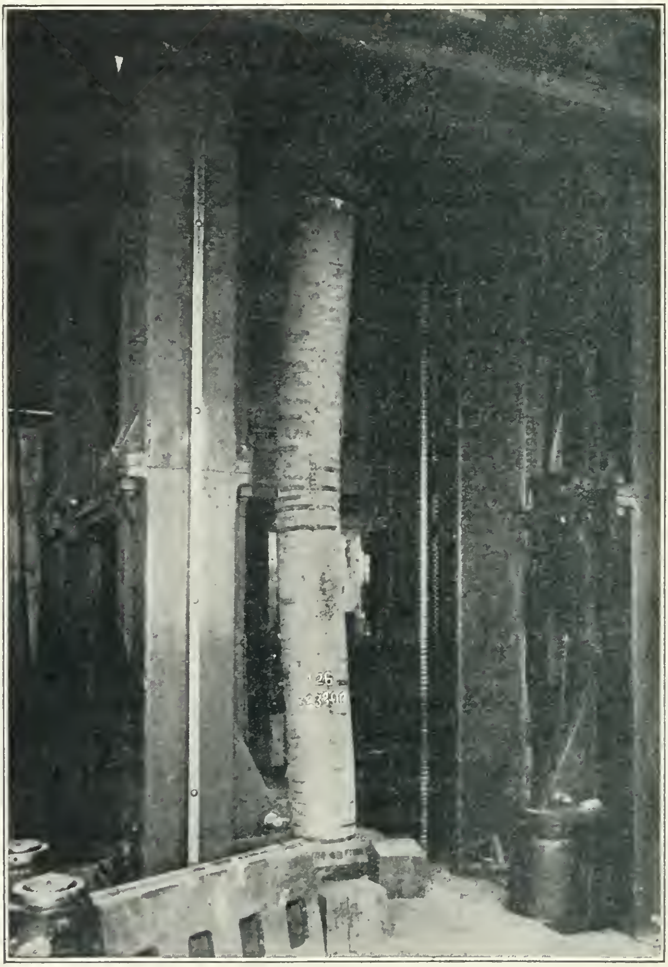
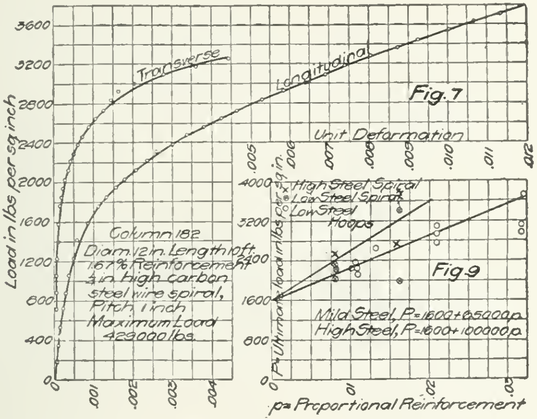


FIG. 6.

elastic limit. Its equation is $P = 1600 + 100{,}000\,p$. The columns reinforced with wire having a yield point of 110,000 pounds per square inch, gave a still higher strength and, of course, a greater amount of shortening. The first term represents the strength of plain concrete columns. These equations are given tentatively as expressing the results of these experiments. Equations of the same general nature may be derived from the results of other experiments on hooped columns.



It may be of interest to note the relation which exists between the load or longitudinal pressure on the column and the lateral pressure which may be considered to act on the hypothesis of hydrostatic pressure to give the deformation of the mild steel bands. Such of these tests as have been studied indicate that this hypothetical lateral pressure amounts to about .35 of the longitudinal pressure acting in excess of the strength of the plain concrete. Comparing the effect of hooping with the additional strength given by longitudinal reinforcement with concrete of the same character (counting in the latter case that the stress in the steel at the ultimate load is twenty-five times as great in intensity as the stress in the concrete), it appears that the additional strength produced by a given amount of reinforcing material is from two to four times as great for the hooped columns as for columns with longitudinal reinforcement. Attention should be called to the fact that since the shortening in a hooped column at the maximum load is several times as great as in a column with longitudinal reinforcement at the yield point of the steel, the effect of combining longitudinal reinforcement and spiral hooping is uncertain.

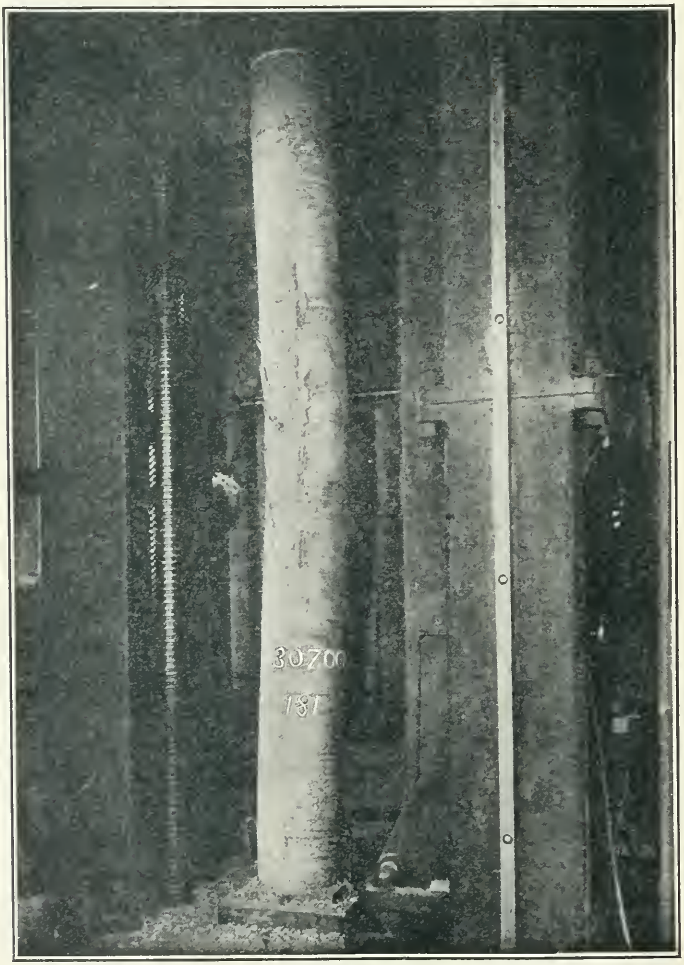


FIG. 8.

An experiment of some interest was made by first loading a hooped column and then stripping the wire from it and testing the naked column. This column was loaded to 2,000 pounds per square inch, and showed a unit shortening of .0036. The load was released and a set of .0025 was found. A load of 2,000 pounds per square inch was again applied, the unit-shortening becoming .0041, and then released. The spiral was then stripped from the column without taking it from the machine and the naked column failed at 1,080 pounds per square inch. As the indications of the stress-deformation diagram are that the plain concrete would have held 1,200 pounds per square inch on first application of the load it may be considered that the concrete sustained 90 per cent. of its original strength. The hooped column itself might have held 2,200 or 2,400 pounds per square inch. A test was made with a column eccentrically loaded. It was found that the hooped column acted as would be expected of a homogeneous column under the same conditions. This may have a bearing upon the explanation of the action of such columns. An analysis based on hydrostatic pressure would require that the internal pressure be distributed uniformly over the column and hence only concentric loading would be allowable.

The writer feels that there is much yet to be learned about hooped concrete, and he has already had to give up several preconceived notions of the action of restrained concrete. As experimental work which helps to clear up uncertainties may be of advantage to the engineering public, the writer presents this matter without waiting for a complete study of the data, and gives the following tentatively as observations on these tests:

1. Poisson's ratio for concrete in compression is a variable quantity, increasing considerably just before the ultimate failure of the concrete. A value of 0.1, or somewhat more, may be tentatively given for the lower loads, and 0.25 to 0.3 near the crushing load. This concrete set in air.

2. In hooped columns the hoops do not come into action to any great extent before a load equivalent to the ultimate strength of plain concrete, or a little below, is reached. The longitudinal deformation and lateral deformation of the concrete is not modified by the hooping to any great extent before this load is reached.

3. Beyond this point both the longitudinal deformation and the lateral deformation are approximately proportional to the added load. The ratio of lateral to longitudinal deformation is more nearly constant, and in these experiments the ultimate strength of the column is controlled by the elastic limit of the hooping.

4. The total amount of shortening before failure occurred was very great, averaging something like eight or ten times that for plain concrete columns, and sixty times that for the ordinary working stress in plain concrete. The longitudinal shortening is, say, eight times that of mild steel at its elastic limit. Cracking and peeling of the concrete appear at loads corresponding to the ordinary ultimate strength of concrete.

5. The excessive amount of shortening before failure affects the problem of combining hooping and longitudinal reinforcement very unfavorably, if the stresses are to be kept within the elastic limit of the latter.

6. The lateral deflection of hooped columns is large and may affect the ultimate strength which is available for the column. For continued application of stress beyond the maximum load, the column deflects enormously. Scaling of surface of concrete, and lateral deflections are warning signs given well before danger of failure exists.

7. The concrete itself retains a considerable element of its strength even after it has been shortened in a hooped state four or five times as much as would produce failure in unhooped concrete columns.

8. Columns of richer and leaner concrete exhibited phenomena of similar characteristics, the hoop stress becoming effective at the ultimate strength of unhooped concrete.

9. Hoops of high elastic limit steel give greater strength than those of mild steel, but the increased amount of shortening necessary to develop the full strength of the column is an undesirable feature.

10. The one experiment indicates that hooped columns will resist eccentric stresses in somewhat the same way as will other material.

11. Light hooping offers security against sudden failures and unevenness of concretes, and will enable higher working stresses to be used. In combination with rich concretes and longitudinal reinforcement, using low stresses in the hoops (*i. e.*, basing the strength upon an assumed ultimate strength but little beyond the average ultimate strength of plain concrete) a satisfactory column may be made. It is suggested that a column of this character may be designed in such a way that the longitudinal reinforcement may

carry the load during construction and still not be overstressed later for the additional stress which goes with the concrete, provided the basal point for the column strength is somewhat below the ultimate strength for plain concrete.

12. Heavy hooping gives added strength, but in utilizing the full strength of such columns the column shortens unduly, deflects laterally, and will strain longitudinal reinforcement many times beyond the deformation which exists at the elastic limit of the metal. It may be applicable where a large limit of safety is desired, or where large variations in shortening are unobjectionable, as where the structure is articulated. So far as ultimate strength is concerned, hooping adds two to four times as much strength to the column as does an equal amount of longitudinal reinforcement.

NOTES ON SOME ADDITIONAL TESTS OF CONCRETE COLUMNS.

By James E. Howard.

In continuing the tests of concrete columns at the Watertown Arsenal Testing Laboratory, reinforcing material has been provided adequate to illustrate the more prominent features pertaining to concrete strengthened by means of external lateral support. Strong hoops and helixes of different sized wires and pitches of coils will be used to reinforce different concrete mixtures.

The two principal questions which present themselves for consideration in the employment of concrete, plain or reinforced, are strength and rigidity. Referring first to reinforcement by means of longitudinal bars imbedded in the concrete, it is evident that ultimate strength may be progressively raised by successive increase of the proportion of steel until finally an all-steel column results, and there can be no doubt that a column composed chiefly of steel will be more rigid than one composed chiefly of concrete, whatever the mixture of the latter may be, although experiments have shown that a small percentage of steel does not promote rigidity, or at least not always. As to the intensity of the compressive stresses in the steel, they become greater over observed parts of the tests as the concrete mixtures are made leaner, a given percentage of steel being present, while the total load carried by the steel will increase in a given concrete mixture as the percentage of metal increases. This states the general behavior of concrete reinforced with longitudinal bars, modifications being introduced affecting the relative loads on the steel and the concrete according to the method of applying the stresses. An inspection of the measured compression deformations given in the details of the Arsenal tests will show the range of stresses taken by the longitudinal bars at different stages of loading. It will be understood that the resistance of the concrete is not increased by the presence of the longitudinal bars, the latter merely relieving the concrete of a portion of the total load placed on the column. The strength of the concrete may, however, seemingly be increased by reason of variations in the intensity of the stresses on the bars giving extra support here and there to zones of local weakness. The adhesive resistance between the concrete and the steel favors action of this kind.

Now, passing to the method of reinforcement by means of external lateral support, here a true increase in the resistance of the concrete may occur, and higher loads attained without impairment of the integrity of structural state. The physical properties of dense materials, so far as known, are not affected by loads of cubic compression, and an efficient system of lateral support introduces conditions approaching those present in cases of cubic compression. If such an end was fully attained in a reinforced column, apparently there would be no practical limit to the strength of the concrete. Of course it is not feasible to provide adequate external support to meet this ultimate possibility, but whatever is accomplished in the direction of the diminished development of strains tends toward increased strength of the material. It is a practical question to judge how far it is expedient to provide reinforcing material, and a problem to experimentally determine in what degree direct compressibility is modified or lateral expansion of the concrete restricted thereby. If it was possible to wrap a finished column with a steel wire helix, putting the concrete under initial strains before loading, maximum strength would be expected. In practice possibly the external reinforcement may not initially be in close contact with the concrete, or it may even be loose in places, and fail to give support during the early stages of loading.

The Arsenal tests in progress are expected to show the degree in which the rigidity of the concrete is influenced by the use of wire helixes, covering the range of material used in current engineering practice. The conditions existing in columns of earlier tests were such that probably no material gain in rigidity was realized from the presence of the exterior reinforcement. The wide range of material to be used in the coming tests should afford information along this line of inquiry. Ultimate strength will be substantially raised, probably, even though the structural integrity of the concrete is not maintained until the maximum load is reached. Loose material within a suitable envelope should necessarily sustain high stresses and transmit loads to parts beyond. Economic as well as engineering questions seem involved in the design and use of reinforced concrete.

Referring now to some columns comprised in the exhibit of the Watertown Arsenal Testing Laboratory at the Jamestown Exposition, two are there exhibited of considerable strength. One is a plain neat cement column, the other a reinforced concrete of 1:2:2 mixture, with a steel wire helix as the principal reinforcement. The neat cement column was loaded with 7,000 pounds per square inch and the test then discontinued. No apparent injury resulted from the application of this load. It is well to bear in mind the load successfully sustained by this neat cement column, when considering the strength of ordinary concrete mixtures. The reinforced column reached a maximum stress of 7,726 pounds per square inch, referred to the sectional area within the steel wire helix. The column had an exterior shell which flaked off before attaining the maximum load, leaving the full stress to be sustained by the concrete enclosed by the helix. Notwithstanding the high resistance displayed by this column, it would probably have reached a still higher limit had not local failure occurred at the upper end where there was about an inch of unsupported concrete above the helix. At the lower end the last coil of the helix came to a bearing against the platform of the testing machine. The reinforcing metal of this column was furnished by Mr. R. Baffrey, President Hennebique Construction Company, New York.

Accompanying these columns was a third one, now sustaining a stress of 1,000 pounds per square inch, the load being maintained by means of steel side rods. This column belongs to a series on the endurance of concrete under long-continued loads, the composition of the column being 1:1:2.

Recognizing the interest which attaches to material in the condition actually used in constructive work, invitations have been extended constructing engineers and others in several cities, requesting them to send to Watertown for test purposes columns made under their direction, representing current work, to be taken directly from work in process of execution. Favorable responses have been received and columns are now in transit to the Arsenal, while others are being made in accordance with this invitation, co-operating with the Arsenal and giving wider scope to the present series of tests by furnishing practical examples of work, supplementary to the laboratory-made columns.

THE EFFECT OF OIL ON CEMENT MORTAR.

By R. C. Carpenter.

I have been unable to find any references to tests showing the effect of oil on concrete,* although the question is often of considerable importance in connection with foundations for machinery. I find that the impression is frequently held among engineers that oil used in machinery is injurious to concrete foundations.

In order to ascertain the effects of oil on concrete, Mr. Sawdon, an instructor in the Mechanical Laboratory of Sibley College, Cornell University, made the following investigations, which, although not sufficient to fully decide the matter, will, I believe, throw some light on the question.

The experiments were conducted by making briquettes of neat cement to which 2 per cent. of oil was added in addition to the water These briquettes were tested for tensile strength at the end of 24 hours, 7 days and 28 days. As a basis of comparison, a test was also made of briquettes made from the same cement in the same manner without the addition of oil. Another series of tests was made on normal briquettes of neat cement which were kept in water 8 days, after which they were soaked in oil for 20 days. Tables I, II and III give the results of the various tests.

TABLE I.—Soundness Pats—Neat Cement.

23 per cent. water.

No.	Treatment.	Test.	Results.	Remarks.
1	1 day in moist air	Boiled 3 hours ..	Sound..	Without oil.
2	1 day in moist air	8 days in linseed oil.	Sound..	Without oil.
3	1 day in moist air	8 days in engine oil.	Sound..	Without oil.
4	1 day in moist air	Boiled 3 hours ..	Sound..	With 2 per ct. linseed oil.
5	1 day in moist air	Boiled 3 hours .	Sound..	With 2 per ct. engine oil.

All the pats adhered to the glass.

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* Since this paper was written the attention of the author has been called to an extensive series of tests upon the effect of oil on concrete by Mr. J. C. Hain, Engineer of Masonry Construction of the Chicago, Milwaukee and St. Paul Railway, published in *The Engineering News*, January 16, 1905.

TABLE II.—TENSION TESTS OF CEMENT MORTAR IN OIL.

Neat Cement. 23 per ct. Water.	Setting.	Days in		Strength in lbs. per sq. in.	
		Air.	Water.	Earth Test.	Average.
No oil........	Allowed to set 24 hours in moist air	I	0	...	430
		I	6	753	696
		I	6	640	
		I	27	735	743
		I	27	751	
2 per cent. linseed oil.	Allowed to set 24 hours in moist air	I	0	190	180
		I	0	170	
		I	6	455	493
		I	6	532	
		I	27	618	572
		I	27	525	
2 per cent. engine oil.	Allowed to set 24 hours in moist air	I	0	320	332
		I	0	345	
		I	6	...	689
		I	27	...	696
No oil........	Allowed to set 24 hours in moist air, 10 days in water and 8 days in oil	Linseed oil.		...	720
		Engine oil.		692	673
		Engine oil..		655	...

TABLE III.—SUMMARY OF RESULTS.

	Lbs. per sq. in.		
	24 hrs.	7 days.	28 days.
Neat cement, no oil....................	430	696	743
Mixed with 2 per cent. linseed oil..........	180	493	572
Mixed with 2 per cent. engine oil..........	332	687	696
Soaked after 8 days in engine oil..........	...	...	693
Soaked after 8 days in linseed oil..........	...	...	720

Considering the results of this experiment, it is noted that the effect of the oil when mixed with the cement is to materially retard the hardening process, and this is more marked with the linseed oil than with the engine oil. Even at the end of the 28-day period the briquettes mixed with 2 per cent. oil were materially weaker than those without oil, although of sufficient strength to pass most specifications.

The soaking of briquettes which were 8 days old, for 20 days in oil, apparently had no material effect when linseed oil was employed, and had a sensible weakening effect when engine oil was used.

The results of the tests referred to are being supplemented by more extensive tests not yet completed. It will be noted in connection with these tests that adding 2 per cent. of oil to the cement did not affect the soundness test.

DISCUSSION.

Mr. L. W. Walter.—Such remarks as I shall make will not cover the subject very broadly. I have made some experiments, however, to determine whether the application of oil to briquette molds would affect the strength of the briquettes. I accordingly added oil to cement in the proportions of one, two and three per cent., and concluded from the results of the experiment that it is safe to use oil on the molds in quantities sufficient to insure against the adhesion of the cement to the molds and thus to provide for more easily cleaning the latter. While my object was not to determine, through extensive tests, the effect of the oil on cement, I found that its presence in the proportions stated, does not seem to be appreciably detrimental. **Mr. Walter.**

Mr. S. A. Brown.—To study the effect of oil on mortars, I made a few experiments in a small way by constructing a number of little bowls of 1 : 2 mortar, using a graded bank sand and putting in these bowls different kinds of oils (linseed, lard, machine and kerosene), I have not as yet (the time being about one year) noticed any evident injurious effect on these mortars although the hydrocarbon oils very readily penetrate any mixture. Even in the case of a neat cement bowl the kerosene completely saturated it. **Mr. Brown.**

I also made bowls which I filled with various solutions. Those which showed signs of affecting the mortar are: ammonium chloride which caused the bowl to crack and split around the edge although the mortar did not disintegrate; vinegar, which attacked the bowl forming a black soft mass easily removed. Caustic soda, lye and sodium carbonate (washing soda) which caused a dissolving of the fine coating on the interior of the bowls and in some cases scaling and cracking, the mortar not disintegrating.

Mr. C. W. Boynton.—Some time ago one of the engineering journals published an account of a test made by the St. Paul Railroad, which, it seems to me, was more extensive than anything mentioned here this morinng. **Mr. Boynton.**

The test was made with different cements used neat, and

Mr. Boynton. extended over quite a long period and with a large variety of oils. I was permitted to see the test pieces, and the effect of oil on some of the cements. The effect of some of the oils on all cements was very marked.

The specimens were made in the form of briquettes and placed in open trays with the oil. In some cases, as I now remember, the briquettes increased in size as much as 75 per cent. In appearance they resembled a very bad specimen under the boiling test. I think anyone interested in this subject would do well to look up the article referred to.

The Chairman. THE CHAIRMAN (Mr. Robert W. Lesley).—I should like to ask whether any one present has ever found that an engine room floor is injured by oil.

Mr. Meade. MR. R. K. MEADE.—We (Dexter Portland Cement Co.) have a great deal of very large machinery in which it is, of course, necessary to keep the bearings bathed in oil all the time. The oil which escapes from these bearings runs into a well, but in spite of this a great deal of it gets over the concrete foundations and in a short time the latter are soaked with oil, yet I have never seen the slightest sign of disintegration in any of our foundations, some of which have been subjected to a continuous drip of oil for over six years.

There is very little reason for making an experiment in which the briquettes are *made* with the water and oil, because that is a condition we do not get in practice. The condition actually met with, is that of cement mortar, fully hardened in air and then surrounded by oil. In nearly all cases too I think the tests had better be made on sand briquettes instead of on neat briquettes and also on briquettes made with normal building sand, as in the latter there are usually a smaller number of voids than are met with in briquettes made with standard sand. The denser the briquette the better it will resist outside agencies. I think if we could get some experiments made along this line the information would be valuable.

Mr. Brown. MR. BROWN.—I should like to ask whether the oil used was animal or vegetable oil. From what I understand of Mr. Griesenauer's tests, disintegration was caused by acids present in vegetable and animal oils. As I have said, I noticed no effect from hydrocarbon oils on the bowls that I made.

Mr. Meade. MR. MEADE.—I do not think there is any question but what

Mr. Meade. there is something in what Mr. Brown says. Cylinder oils and oils of that class, in which animal oils are put for the purpose of making them adhere better to the wet cylinder, are all in time partially decomposed forming quite a bit of fatty acid. I may say in this connection, however, that concrete will resist weak acids very well, and these fatty acids are very weak ones. At Lafayette College, some years ago, we built a new chemical laboratory, in which we desired to line the hoods with some fire-proof material. The floors to these hoods were subjected to more or less strong mineral acid, spilled upon them by careless or inexperienced students. We tried first lining the hoods with a mixture of cement and limestone, but found that wherever acids were dropped the concrete was eaten away according to the amount of acid spilled, etc. When we used sand, however, we found that the acid when spilled ate a little bit of the cement out of the concrete, but that there was deposited in its place gelatinous silica, which is itself a fairly good cement and which at any rate stops up the pores of the concrete and protects it from further corrosion by the acid. Where cement has to withstand the action of oils liable to form fatty acids, therefore, it might be well to use a sand and gravel concrete, as the more resistant to acids. I must say, however, that our foundations at the mill are all made with crushed cement-rock (argillaceous limestone) and we have never observed any disintegration in that part of them exposed to the oils.

Mr. Boynton. MR. BOYNTON.—By my previous remarks, I do not wish it understood that I fear the effect of oil as it may come in contact with concrete in practice. I have never seen machinery foundations affected by the drippings of oil upon them.

Mr. Walter. MR. WALTER.—I have heard of the failure of cement to set or harden attributed to the presence of crude oil in the mixing water. I don't know that I can name any particular case where the failure of cement to act properly was due to the presence of oil in the water, I have heard of instances where, apparently, this peculiar action could be attributed to no other cause, and I think the impression is had, to some extent, that it is not safe to use surface water from the vicinity of an oil well in mixing concrete. I do not wish to be understood as supporting this claim, but I should like to hear from some cement manufacturers to learn whether they have any trouble from this source.

NVESTIGATION OF THE THERMAL CONDUCTIVITY OF DIFFERENT CONCRETE MIXTURES AND THE EFFECT OF HEAT UPON THEIR STRENGTH AND ELASTIC PROPERTIES.

By Ira H. Woolson.

This paper is a record of experiments made in continuation of an investigation begun two years ago, and partially reported at the two previous meetings of this Society. (See Vols. V and VI.)

Conductivity Tests.

It was found last year that thermo-couples imbedded in blocks of concrete for purpose of measuring internal temperatures when the blocks were heated, were likely to be shifted in tamping the wet mixture, thus making it difficult to measure the temperature from exact positions. To obviate this trouble a single specimen was made with a series of holes running in from the back face to points at definite distances from the front face to which heat was applied. The results obtained from this plan were so satisfactory it was decided this year to repeat the experiment using trap, gravel, and cinder mixtures for comparison.

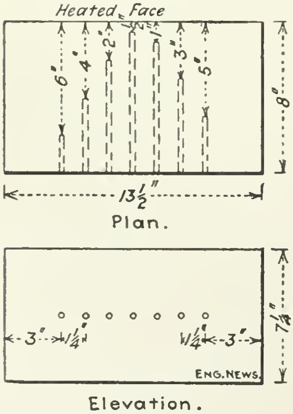

Fig. 1.

Two specimens of each mixture were made. Fig. 1* gives the size of the blocks, and the location of the holes in which the thermo-couples were placed. The arrangement was varied slightly from last year, in order to keep the outside couples from being affected by heat transmitted through the ends of the blocks from the furnace walls. The blocks were placed for test in the gas furnace doorway, the same as last year (see Vol. VI, p. 440, Fig. 8). Seven couples were used, and were so located as to indicate the temperature at points varying from $\frac{1}{2}$ inch to 6 inches from the heated face. It was found that this arrangement of couples nearly eliminated the effect of heat from the side walls. The method of test was essentially the same as that described last year, except that the duration of the test was cut from five hours to two hours. It was decided that the shorter period would give sufficient evidence to classify the different mixtures while effecting a considerable saving in time.

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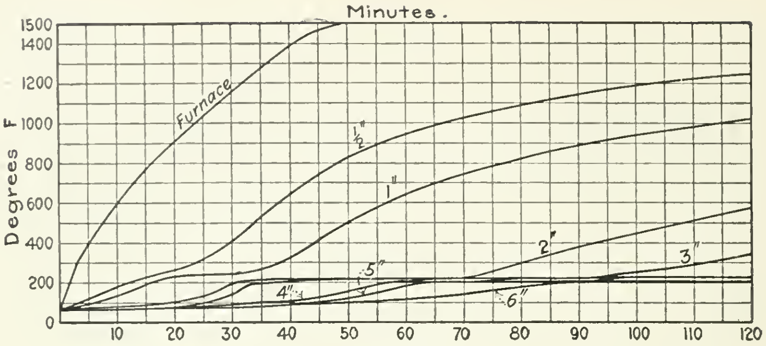
* Acknowledgment is made to the *Engineering News* for most of the cuts used in this paper.

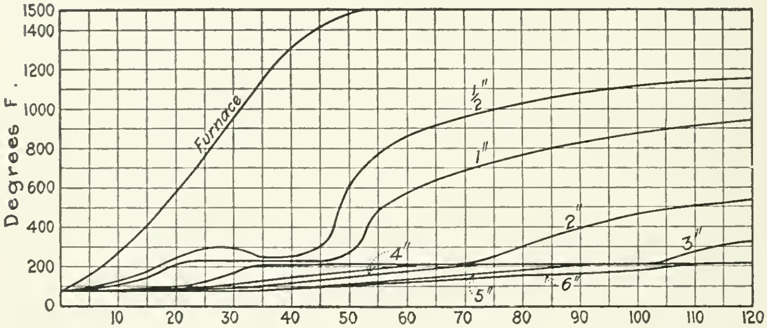
The aggregate used was a 1–2–4 mixture of cement, sharp sand, and $\frac{3}{4}$ in. crushed trap rock, or a corresponding size of clean quartz gravel. In the cinder mixture the proportion was changed to 1–2–5, and the cinder employed was a fair quality boiler cinder, with most of the fine ashes removed. The cement was an equal mixture of Atlas, Lehigh and Vulcanite. The concrete was mixed moderately wet, and well tamped. The specimens were left in the molds 24 hours, then placed in water for 48 hours; after this they were kept moist for two to three weeks, after which they were given a good opportunity to dry. They were about two months old when tested.

In making the tests the furnace temperature was brought up to 500° F. in approximately 45 minutes and held there throughout the remainder of the test. Figs. 2 and 3 are the curve sheets for these tests. Each curve is marked with a figure indicating the distance from the heated surface at which the readings were taken. There are duplicate tests of each mixture. The shape of the curves is much the same as those of last year. There is the characteristic lag at the 212° point, due to the evaporation of water in the concrete. The time required to do this increases with the distance inward from the heated face.

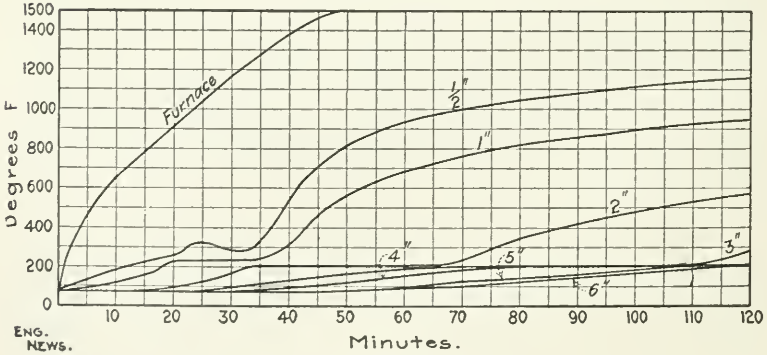
In Fig. 2 it will be noted that the curves for some of the points nearest the heated surface have a marked depression between the two and three hundred degree limits. This is probably due to the fact that the outer surface of the block was dried out to a depth of one or more inches and the heat in this region rose gradually until it penetrated to the moisture further in the block, causing it to expand and forcing it outwards towards the heated portion where it



Cinder.

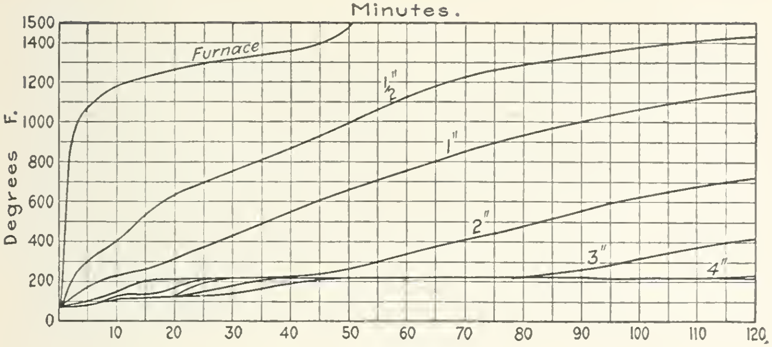


Gravel.

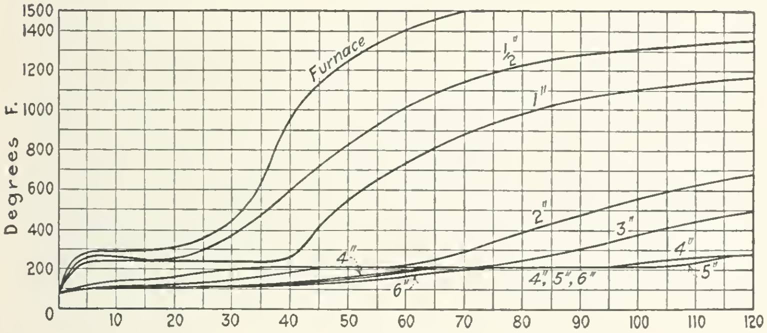


Trap.

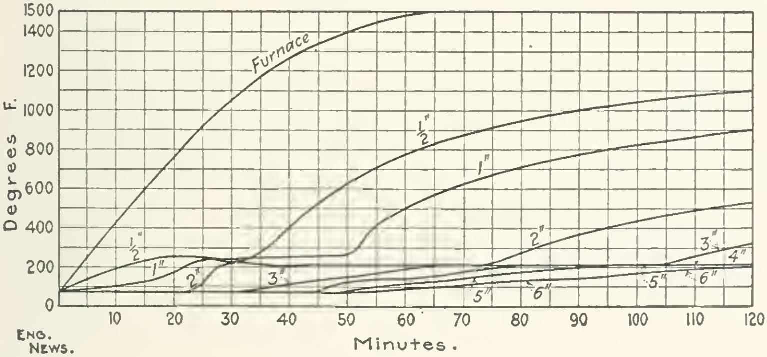
FIG. 2.



Cinder.



Gravel.



Trap.

FIG. 3.

was turned into steam, thus absorbing the heat, and lowering the temperature. When the moisture was evaporated, the temperature rose again in the regular way. This peculiarity is not noticeable in the cinder concrete, probably for the reason that the concrete being more porous, dried out better, and for the same reason permitted the heat to drive what moisture there was before it through the block. The curves of Fig. 2 are permissible of very close comparison since the specimens were all of the same age ($2\frac{1}{2}$ months) and all in the same condition. The curves of furnace temperature are also practically the same. It will be noted that the conductivity characteristics for trap and gravel are almost identical, and that cinder is a better conductor than either.

In Fig. 3 the curves are not quite so satisfactory for two reasons. First, the furnace temperatures were not as well regulated, due to various causes beyond control, and secondly, two of the specimens had been subjected to a hot drying atmosphere for several days in an effort to get rid of the interior moisture. However, the results are of value as confirmatory evidence.

The conclusions we may draw from this data are: That all concretes have a very low thermal-conductivity, and herein lies their ability to resist fire. That when the surface of a mass of concrete is exposed for hours to a high heat, the temperature of the concrete one inch or less beneath the surface will be several hundred degrees below the outside. That a point two inches beneath the surface would stand an outside temperature of 1,500° for two hours, with a rise of only 500 to 700°, and points with three or more inches of protection would scarcely be heated above the boiling point of water.

The fact that the cinder concrete showed a higher thermal-conductivity than the stone concrete would indicate that its well-known fire-resistive qualities are due, in part at least, to the incombustible quality of the cinder itself.

Although the thermal-conductivity of the gravel concrete was fully as low as that of the trap, it must nevertheless be condemned as a first-class fire-resisting mixture. All the specimens of gravel concrete tested were badly disintegrated by the heat. The gravel specimens would crack and crumble in pieces when the trap and cinder specimens under similar treatment would remain firm and compact. These results are in complete confirmation of those reported last year which were received by some of the membership with considerable skepticism. The writer is convinced that concrete made from this particular gravel is not reliable as a fire resisting material. Whether other grades of gravel would give equally unsatisfactory results is a matter for investigation.

The cause for this failure of the quartz mixture is not easy to locate. The most plausible reason seems to be the relatively large coefficient of expansion of the quartz. It is about twice that of feldspar, which is one of the predominant minerals in trap rock. Clark's "Constants of Nature," published by the Smithsonian Institute, gives the cubical coefficient of expansion for these minerals as follows:

Quartz	.000036
Feldspar	.000017

According to the same authority, quartz has another peculiarity of expansion, viz., that the expansion in the direction of the major axis is only half that in the direction of the axis perpendicular to the major axis. This unequal expansion may further contribute to its tendency to disintegrate the concrete under action of heat.

Since the distribution of gravel is much more general than trap, the subject is of much importance and tests should be made to determine if other gravels are equally defective.

CONDUCTIVITY OF IMBEDDED STEEL.

In connection with the investigation of the conductivity of concrete itself, some tests were made to determine the conductivity of steel imbedded in concrete. In making fire tests upon full size reinforced concrete floors the writer has noticed that a reinforcing rod exposed for hours to a bright red heat would only develop a temperature of a few hundred degrees in adjacent portions imbedded two or three feet in the concrete. This fact suggested the idea of this part of the investigation.

The specimens for this test were made by imbedding ¾ in. square steel bars in blocks of concrete 3 ft. long and 8 in. square. The bars projected 6 in. beyond the end of the concrete. Holes ¼ in. deep were drilled into the bars at regular distances apart, and corresponding holes made in the concrete. (See Fig. 4.) Two specimens of each mixture were made under the same conditions as the other specimens, and were tested when about two months old. Two specimens at a time were placed with the projecting bars in the doorway of the furnace, the concrete being of such size that it completely filled the openings.

Thermo-couples were inserted in the holes in the bars nearest the fire, and thermometers in the others. The temperature of the furnace was raised to 1,700° F. in an hour and held there for an hour longer. Temperatures were read in each hole every five minutes. The idea of the test was that the projecting ends of the bars would be held at a high heat while the concrete would be comparatively cool except the end which faced the fire.

The results are shown in the curves in Figs. 5 and 6. Each curve is numbered and the following table indicates the distance of the point at which readings were taken for that curve, from the heated face of the concrete.

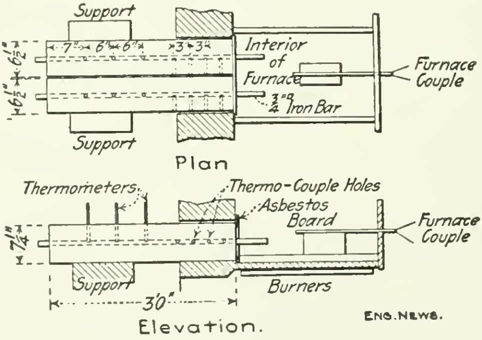
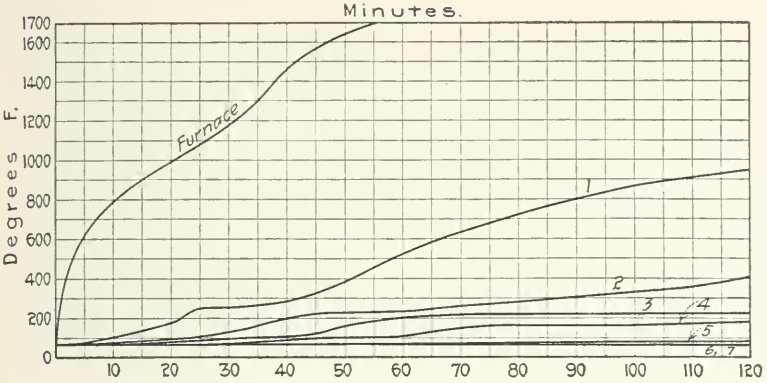


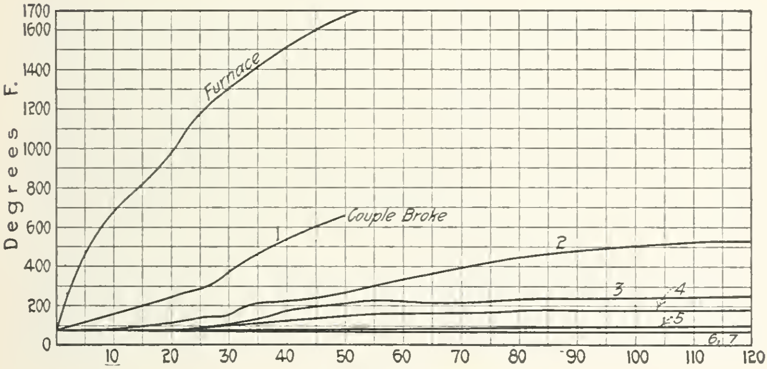
FIG. 4.

No. 1— 2 inches from heated face.
No. 2— 5 “ “ “ “
No. 3— 8 “ “ “ “
No. 4—11 “ “ “ “
No. 5—17 “ “ “ “
No. 6—23 “ “ “ “
No. 7—29 “ “ “ “

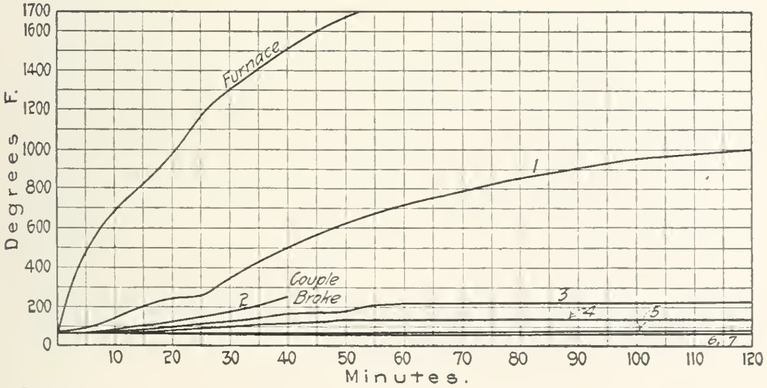
As iron is known to be a good conductor of heat it was expected that a considerable portion of the imbedded bar would attain a temperature nearly that of the exposed end. It was therefore surprising to find that after the projecting end of the bar, and the end face of the concrete had been held at a temperature of



Cinder.



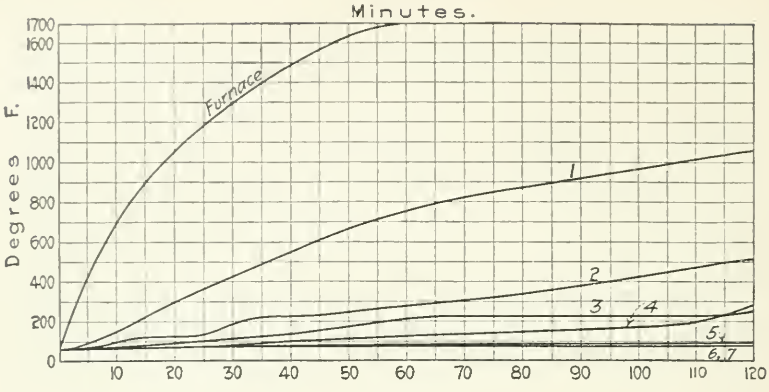
Gravel.



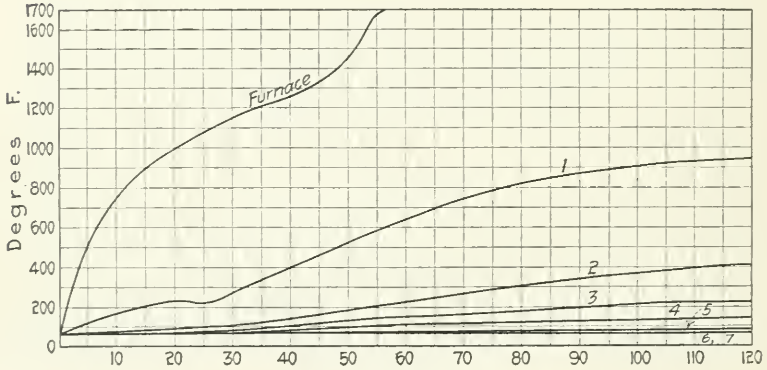
ENG NEWS.

Trap.

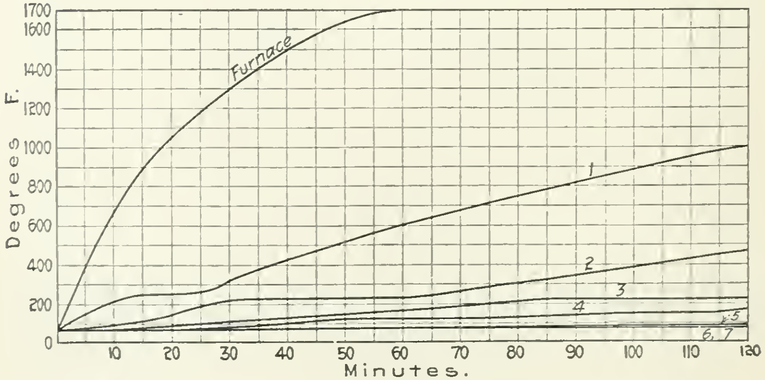
FIG. 5.



Cinder.



Gravel.



Trap.

ENG. NEWS.

FIG. 6.

1,700° for an hour, a point in the bar two inches from the heated face of the concrete had developed a temperature of only 1,000°, or a drop of 700°. Fig. 5 shows this very clearly. It also shows that a point five inches in the concrete acquired a temperature of only 400° to 500°. Also that a point eight inches in, only reached the temperature of boiling water, and the balance of the bar retained very little heat. The results were practically the same for all three mixtures. The curves show the usual lag due to moisture, but this is less apparent in the cinder mixture, showing it was dryer. Although these results are very interesting, it was discovered that they were somewhat misleading, for by testing one of the same bars without the concrete in the open air with one end heated over a gas furnace, it was found that the travel of heat along the bar was really very small. Only a single test was made, but it served to demonstrate the fact that air radiation protected the bar from heat as well as the concrete. Fig. 7 shows the results of this test. The points are the same as in the previous tests. The test was continued for only one hour, for the parallelism of the curves indicated that the rate of radiation was just equaling the rate of reception.

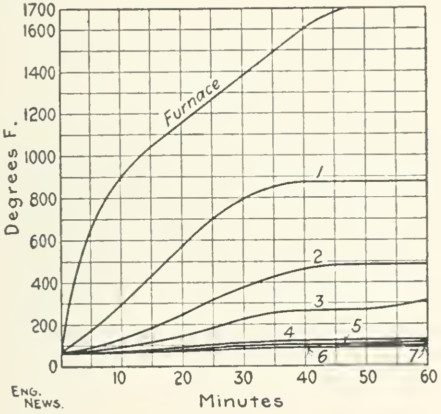


FIG. 7.

These experiments indicate that where reinforcing metal is exposed in the progress of a fire, only so much of the metal as is actually bare to the fire is seriously affected by it.

STRENGTH TESTS.

A few tests were made to determine the strength and elasticity of the different mixtures both with and without heat treatment. The results of these tests are given in the following tables.

The heat was raised to 1,500° F. in 45 minutes and held there for the remainder of the test.

The tables show the usual deterioration due to heat, also that the trap was decidedly the strongest mixture both before and after heating. The gravel was next in grade when unheated, but was a complete failure after heating even for one hour on one side only. The cinders gave the least strength of all—about half that of the trap, with corresponding weakening due to heating.

TABLE I.

7 x 7 x 7 in. Specimens–Age, 2 months.

Material.	Breaking load. Lbs. per sq. in.		
	Not heated.	Heated all over 1 hr.	Heated all over 2 hrs.
Trap	a—2,460 b—2,520	1,690 1,767	1,011 1,198
Gravel	a—1,684 b—1,730	(crumbled in pieces)	(crumbled in pieces)
Cinder	a—1,090 b—1,420	621 796	455

TABLE II.

6 x 6 x 14 in.–Prisms.

Material.	Breaking load. Lbs. per sq. in.		
	Not heated.	Heated one side 1 hr.	Heated one side 2 hrs.
Trap	a—1,945 b—1,845	1,280	1,120
Gravel	a—1,370 b—1,355	a—broke while handling. b—800	
Cinder	a—978 b—873	a—800 b—810	

TABLE III.

Elastic Properties of 6 x 6 x 14 in. Prisms.—Age, Two Months.

Material.	Modulus of Elasticity (E) at								
	200 lbs. per sq. in.			400 lbs. per sq. in.			800 lbs per sq. in.		
	Unheated.	Heated 1 hour.	Heated 2 hours.	Unheated.	Heated 1 hr.	Heated 2 hours.	Unheated.	Heated 1 hour.	Heated 2 hours.
Trap........	2,180,000	182,000	348,000	2,000,000	255,000	296,000	1,789,000	304,000	309,000
Gravel.......	828,000	98,000	....	858,000	132,000	....	960,000	171,000	....
Cinder.......	858,000	255,000	....	685,000	283,000	....	505,000	218,000	....

It should be stated that the results contained in Tables II and III are somewhat deceptive, because the specimens were all heated to a considerable extent upon three sides. It was impossible to prevent heat from radiating from the furnace walls into the

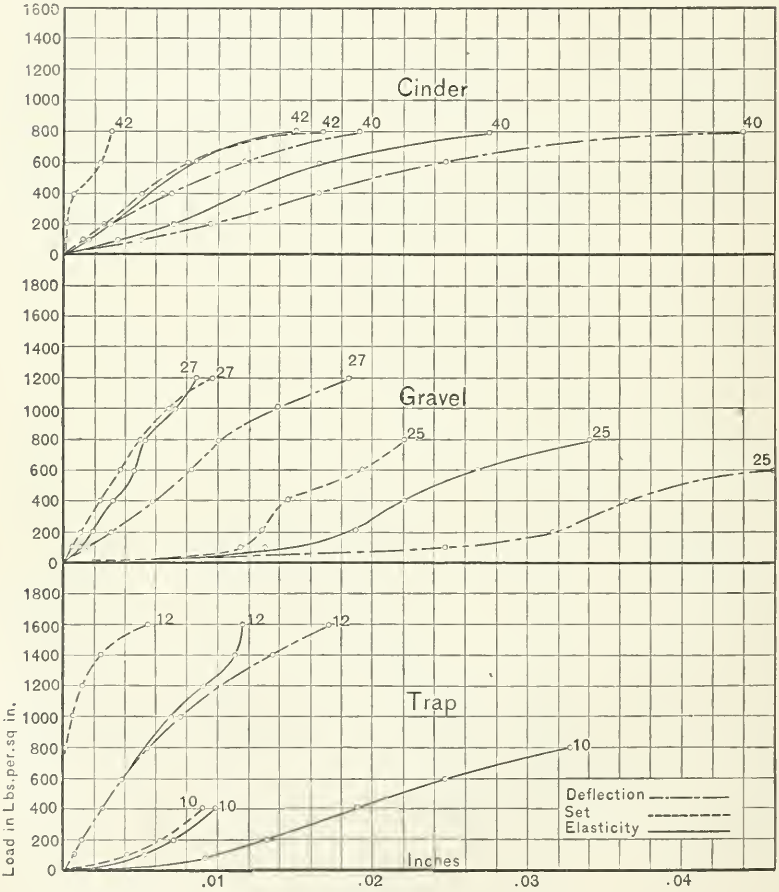


FIG. 8. 42.—Unheated.
40.—Heated one hour on one side.
27.—Unheated.
25.—Heated one hour on one side.
12.—Unheated.
10.—Heated one hour on one side.
All heating at 1,500° F.

sides of the specimen adjacent to the regularly heated face. For the purpose of comparing the different mixtures after heating, the results are reliable, but in general they are lower than they

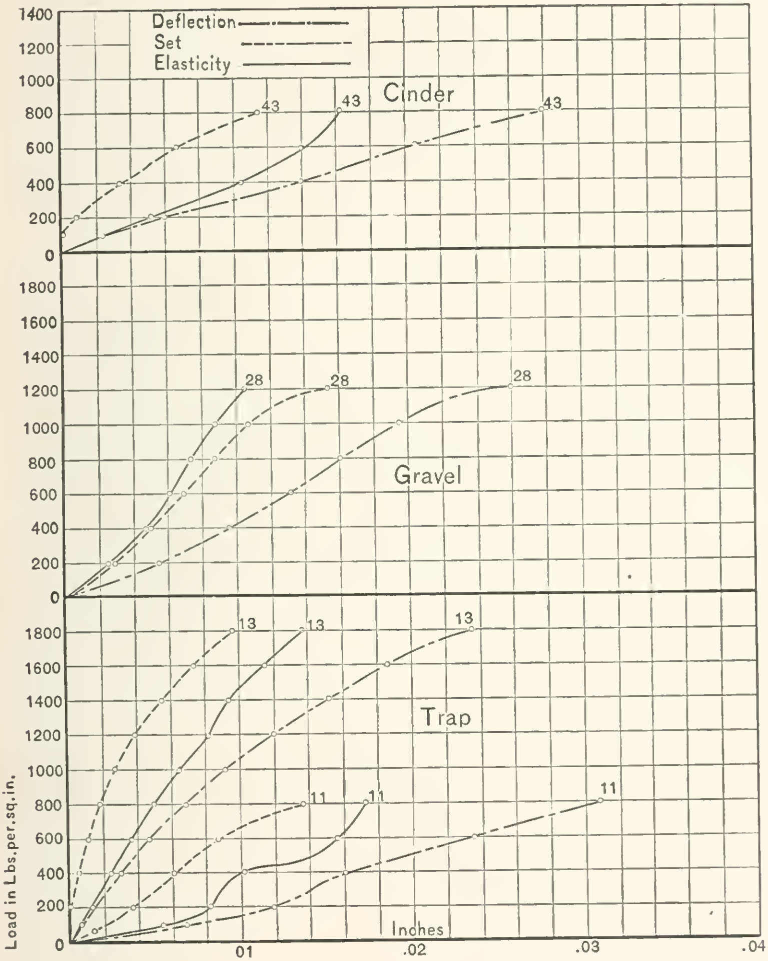


FIG. 9. 43.—Unheated.
28.—Unheated.
13.—Unheated.
11.—Heated for two hours on one side at 1500° F.

would be if the specimens had been built in a wall where little, if any, heat would have reached the sides.

The specimens were set up for making elastic measurements, in the same manner as last year (see Vol. VI, p. 447, Fig. 15). Figs. 8 and 9 are elastic curves plotted to show the full deflections, the sets, and the differences.

The laborious part of the investigation this year, as in the past, was done by students as a thesis problem. Messrs. R. D. Bailey, R. C. Jones and H. R. Smith devoted themselves to the work with an earnestness of purpose that was fully in accord with those who had preceded them, and they deserve much credit for the care with which the work was done.

SUMMARY.

As a summary of the reports of the three investigations, we may draw the following general conclusions:

(1) That all concrete mixtures when heated throughout to a temperature of 1,000° to 1,500° F. will lose a large proportion of their strength and elasticity, and this fact must be well remembered in designing.

(2) That all concretes have a very low thermal conductivity and therein lies their well known heat resisting properties.

(3) That as a result of this low thermal conductivity, two to two and a half inches of concrete covering will protect reinforcing metal from injurious heat for the period of any ordinary conflagration (provided, of course, that the concrete stays in place during the fire).

(4) That reinforcing metal exposed to the fire will not convey by conductivity an injurious amount of heat to the imbedded portion.

(5) That the gravel concrete was not a reliable or safe fire resisting aggregate.

DISCUSSION.

Mr. Humphrey

MR. R. L. HUMPHREY.—The tests we made at the Underwriters' Laboratory in Chicago on concrete composed of various aggregates, including gravel, while made under different conditions, perhaps, from the tests by Professor Woolson, have given different results. I think there is some truth in the explanation that the behavior of gravel under the action of heat is due to differences in the coefficient of expansion of the quartz particles. I presume, however, that this condition will vary with different gravels, and while Professor Woolson's experience may be true of the gravel that he used in his testing, it does not necessarily follow that it will be true of all gravels. The gravel which we used in the Chicago test was obtained from the Meremac River near St. Louis, and was 60 days old at the time of testing. It was submitted to a temperature of 1,750° F. for two hours, after which it was immediately quenched by a stream of water under 50 pounds pressure at a distance of 20 feet. The concrete blocks so tested were a part of a series of plain-beam tests made in St. Louis. The concrete was a rather wet 1–2–4 mixture. After the testing, the surface had flaked off somewhat but there was no serious disintegration of the concrete such as took place in Professor Woolson's tests. The extent of the surface damage did not exceed $\frac{1}{4}$ of an inch. Other samples of cinder concrete, gravel concrete and limestone concrete were tested in a similar manner. It is quite evident from the various fire tests made in Chicago that the character of the mixture has a great deal to do with its endurance. A poor mixture made with very little water would suffer greater damage under fire test than a thoroughly wet and well compacted mixture.

It was also apparent from this test that limestone may be successfully used as an aggregate as far as its fire resistance is concerned, if the limestone particles are kept back from the face and are protected with a coating of mortar made from silicious sand. The strength of mortars and concretes are proportional to their density and these tests seem to indicate that the fire resisting quality is also proportional to the density.

Mr. Humphrey. The results of these fire tests also indicate that of the various materials used for fire-proofing purposes, concrete passed this severe test as creditably as any of these materials. Professor Woolson's investigations have been excellent and I hope he will continue them, carrying them out on a more extensive plan with the view of definitely establishing the correctness of the points which he has brought forth in his paper.

Mr. Brown. MR. JOHN G. BROWN.—I should like to ask Mr. Humphrey as to the kind of pyrometer he used and whether its readings were fairly comparable with those of the pyrometer used by Professor Woolson.

In heating limestone I have found some that did not seem to be much affected even after having been subjected to a white heat, while others decomposed almost immediately.

Mr. Woolson. MR. IRA H. WOOLSON.—We used Le Chatelier pyrometers with platinum-iridium couples; and we carefully standardized those couples before the tests with pure metals up to the melting point of gold. Within reasonable limits the results obtained from those points are therefore correct.

I want to say a word with regard to the tests mentioned by Mr. Humphrey. He says those were taken from the fire and immediately subjected to water. That, probably, is one reason why they are in as good condition to-day as they are. We notice in fire tests of floor construction that where the concrete is thoroughly soaked with water after a test which has calcined the mortar, a reset will take place and the concrete be stronger in consequence.

Mr. Humphrey. MR. HUMPHREY.—The temperatures were measured, as in the case of Professor Woolson's tests, with Le Chatelier pyrometers and I may add that Professor Woolson was good enough to undertake the standardization of our pyrometers in his laboratories. In addition to these Le Chatelier pyrometers which projected through the face of the panel at different points, there was hung in the fire chamber a water pyrometer, which gave the average temperature of the furnace, and which indicated practically the same average temperature as the Le Chatelier pyrometers.

NOTES ON THE EFFECT OF TIME ELEMENT IN LOADING REINFORCED CONCRETE BEAMS.

By W. K. Hatt.

During the last two years the Laboratory for Testing Materials of Purdue University, in co-operation with the U. S. Geological Survey, has made some experiments to determine the effect of the time element in loading reinforced concrete beams. In these experiments beams were loaded in the following manner:

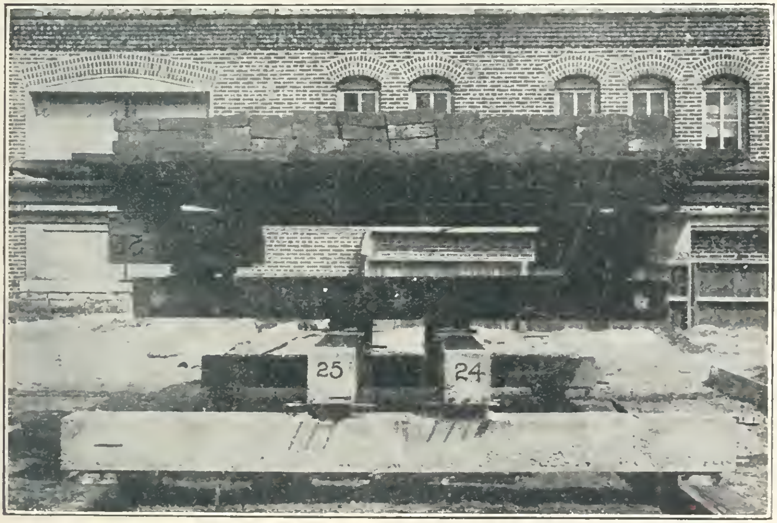


Fig. 1.

1. The ordinary test in which continuously increasing loads are applied until failure.

2. Loads applied a number of times from zero; starting with a repeated load causing about 3,000 pounds per square inch stress

TABLE I.—DEFLECTION OF REINFORCED CONCRETE BEAMS UNDER REPEATED LOADINGS.

Deflections and set in inches.

Approximate stress in steel.	Load. Lbs.	Beam No. 12.			Beam No. 15.			Under constant load for two months.	No. 18. Ordinary testing machine load.
		Number of times applied.	Deflection.	Set.	Times applied.	Deflection.	Set.		
3,000	2,400	1	.025	.005	1	.025	..	0.100	.050
		710	.035	.005					
8,000	5,200	1	.070	.010	1	.070	.010	0.160	.08
		500	.170	.060	500	.140	.050	....	..
16,000	6,750	1	.210	.060	1	.180	.060	0.290	0.14
		700	.260	.100	450	.240	.080	...	..
29,700	8,100	1	.300	.100	1	.270	.090	0.360	0.21
		470	.310	.120	620	.290	..	...	..

TABLE II.—COMPARISON OF MAXIMUM LOADS.

Beam No.	Reinforcement.		Span. Feet.	Loading.		Maximum Load.
	Per cent.	Kind of bars.		Times.	Load.	
1907.						
18	1	Round.	9	Continuous	....	9,800
15	"	"	9	500	5,200	....
				450	6,750	....
				620	8,100	9,550
16	"	"	9	60	8,100	9,675
17	"	"	9	60	8,100	8,720
19	"	"	9	169	6,230	9,360
12	"	"	9	700	2,400	....
				500	5,200	....
				700	6,750	....
				470	8,100	10,650
15	....	"	9	500	5,200	....
				450	6,750	....
				620	8,100	9,550
1906.						
9, 11	1.5	"	8	Continuous.	....	24,600
12	1.5	"	8	1,776	....	25,000
2, 7, 10	1.5	"	12	Continuous.	....	15,970
8	1.5	"	12	611	....	15,850
3, 4	0.75	Corr.	12	Continuous.	....	15,600
6	0.75	"	12	1,248	....	15,900

in steel, and stepping up to 8,000, 16,000, 29,000, and then to failure.

3. Constant loads.
4. Impact tests.
    (*a*) Under increasing height of drop.
    (*b*) Under constant height of drop.

This paper only records the general results of these tests which are to be published in full later.

TABLE III.—REINFORCED BEAMS UNDER IMPACT.

Increasing height of drop.

Beam No.	At Elastic Limit.		At Failure.	Remarks.
	Height of drop. Inches.	Deflection. Inches.	Height of drop. Inches.	
2	12.25	.25	16	Wt. of hammer, 250 pounds.
3	9.20	.20	11	Test under increasing height of fall.
4	11.25	.25	14	Increment 2 inches.
5	14.25	.25	16	Span 6 ft.–8 in. x 8 in. x 7 ft.–1 per cent. steel.

Constant height of drop.

Beam No.	Constant fall of 10 inches.	Average deflection per blow. Inches.	Number of blows at failure.	Age in days.	Remarks.
6	....	.070	40	124	100-pound hammer with drop of 10 inches
7	....	.065	55	131	
8	....	.070	65	133	
9	....	.073	76	151	
10	....	.075	112	153	

MATERIAL TESTED.

The beams were of broken stone concrete in proportion 1–2–4; 8 inches wide and 10 inches to the depth of the steel under 1, 2 and 3. Ordinarily the span was fixed at 9 feet and the loads were applied to third points. The percentage of steel was ordinarily 1 per cent., but varied as shown in Table II. The age at test was intended to be 60 days. Since some of the

TABLE IV.—DEFLECTIONS OF BEAMS UNDER CONSTANT LOAD.

Stress Figured.	Beam No.	APRIL.																	MAY.		
		11	12	13	15	16	17	18	19	20	22	23	24	25	26	27	29	30	1	2	3
3,000 ..	22	.04	.04	.04	.04	.04	.04	.04	.05	.05	.05	.05	.05	.05	.07	.07	.08	.08	.08	.08	.08
3,000 ..	23	.04	.04	.04	.04	.04	.04	.05	.05	.05	.06	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07
8,000 ..	26	.10	.10	.10	.10	.10	.11	.11	.11	.11	.11	.11	.13	.13	.13	.13	.13	.13	.13	.13	.13
8,000 ..	21	.10	.10	.11	.11	.11	.11	.11	.11	.11	.11	.11	.13	.13	.13	.13	.13	.13	.11	.11	.11
16,000 ..	24	.15	.15	.15	.15	.15	.16	.17	.17	.17	.18	.20	.21	.22	.22	.22	.22	.22	.23	.23	.23
16,000 ..	25	.14	.15	.15	.15	.16	.17	.17	.18	.18	.19	.20	.21	.21	.21	.22	.22	.22	.24	.25	.25
29,700 ..	28	.20	.21	.21	.21	.21	.21	.23	.23	.23	.23	.25	.28	.30	.30	.30	.31	.31	.31	.31	.31
29,700 ..	27	.20	.20	.20	.21	.21	.21	.22	.23	.23	.23	.24	.28	.33	.33	.33	.35	.35	.35	.35	.35

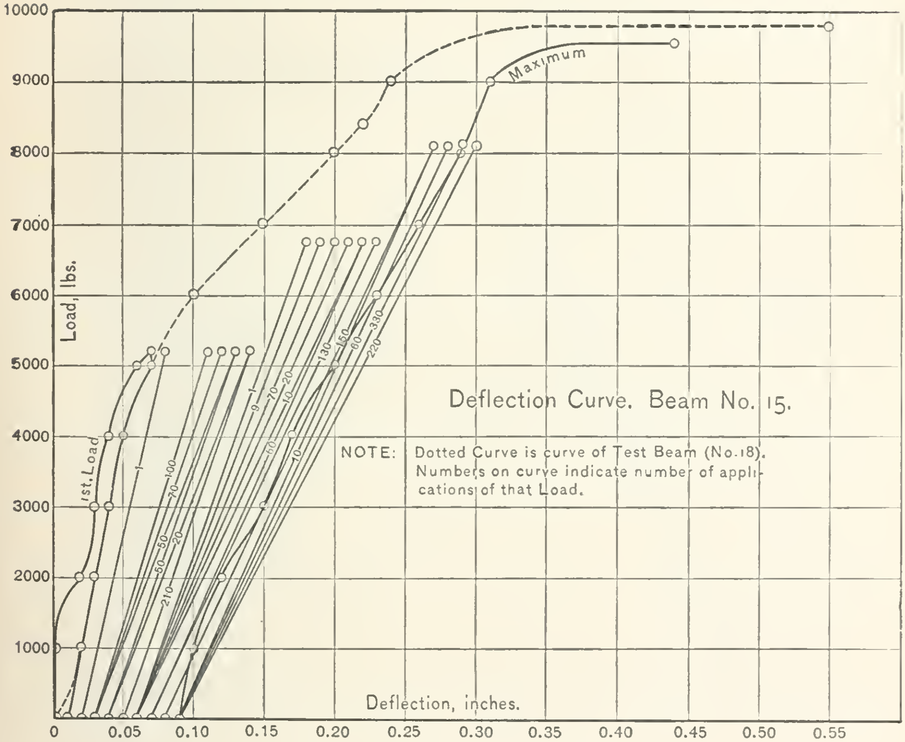
Stress Figured.	Beam No.	MAY.																		SEPT.	
		4	6	7	8	9	10	11	13	14	15	16	20	21	22	23	24	25	28	18	23 Set
3,000 ..	22	.08	.08	.08	.08	.08	.08	.08	.09	.09	.09	.09	.09	.10	.10	.10	.10	.10	.10	.12	.05
3,000 ..	23	.07	.07	.07	.07	.07	.07	.07	.09	.09	.09	.09	.10	.10	.10	.10	.10	.10	.10	.15	.08
8,000 ..	26	.13	.14	.14	.14	.14	.14	.14	.16	.16	.16	.16	.17	.18	.18	.18	.18	.18	.17	.25	.11
8,000 ..	21	.11	.11	.11	.11	.11	.11	.11	.12	.12	.12	.13	.14	.15	.15	.15	.15	.15	.16	.18	.15
16,000 ..	24	.23	.23	.23	.23	.23	.23	.23	.24	.24	.24	.24	.25	.25	.25	.25	.27	.27	[.50]	.58	.49
16,000 ..	25	.25	.25	.25	.25	.25	.25	.25	.27	.27	.27	.27	.28	.28	.28	.28	.30	.31	[.97]	.18	1.05
29,700 ..	28	.31	.31	.31	.31	.31	.32	.32	.32	.32	.33	.33	.33	.33	.33	.33	.34	.34	.35	.48	.34
29,700 ..	27	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.37	.37	.37	.37	.38	.38	.38	.49	.39

NOTE.—Deflection readings on September 18 and set readings on September 19 have been added since paper was presented.

beams were loaded nearly 2,500 times by hand, the duration of the test in some cases was nearly a month.

METHOD OF TEST.

Process 1.—Loads were applied at third points, and deflections were measured at the center of the beam. Extensometer measurements were made of the deformations occurring at the top and bottom faces of the beam, which measurements were made in the same manner as practised at the Structural Materials Laboratory of the U. S. Geological Survey, at St. Louis.



Deflection Curve. Beam No. 15.

NOTE: Dotted Curve is curve of Test Beam (No. 18). Numbers on curve indicate number of applications of that Load.

FIG. 2.—Repeated Loading.

Process 2.—The details of the test were as described under Process 1, except that a certain stage of loading would be repeated a large number of times until the beam seemed to come down to its bearing under that loading. The deflection was read every 10th loading, and extensometer readings were made at intervals, usually every 100th loading.

Process 3.—Pairs of beams were piled one upon the other as shown in Fig. 1 and submitted to a constant load for a period of some two months. The span between the bearing points was so varied as to cause an increase in stress in the steel from 3,000 to 8,000 to 16,000 to 29,000 pounds per square inch from the top pair of beams to the bottom pair of beams. Rollers were disposed between all bearing points so that the beams might act independently.

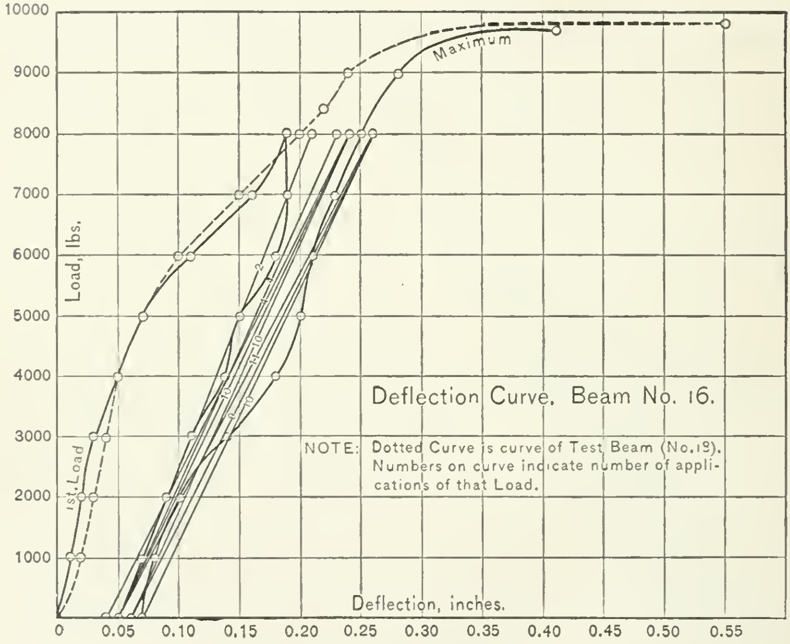


FIG. 3.—Repeated Loading

Unfortunately, after the expiration of about two months, some trespassers on the laboratory grounds caused a swaying back and forth of the steel rails supporting the constant load, and threw the entire load on one of the pair of beams intended to be stressed to 16,000 pounds in the steel. The yield point of the steel

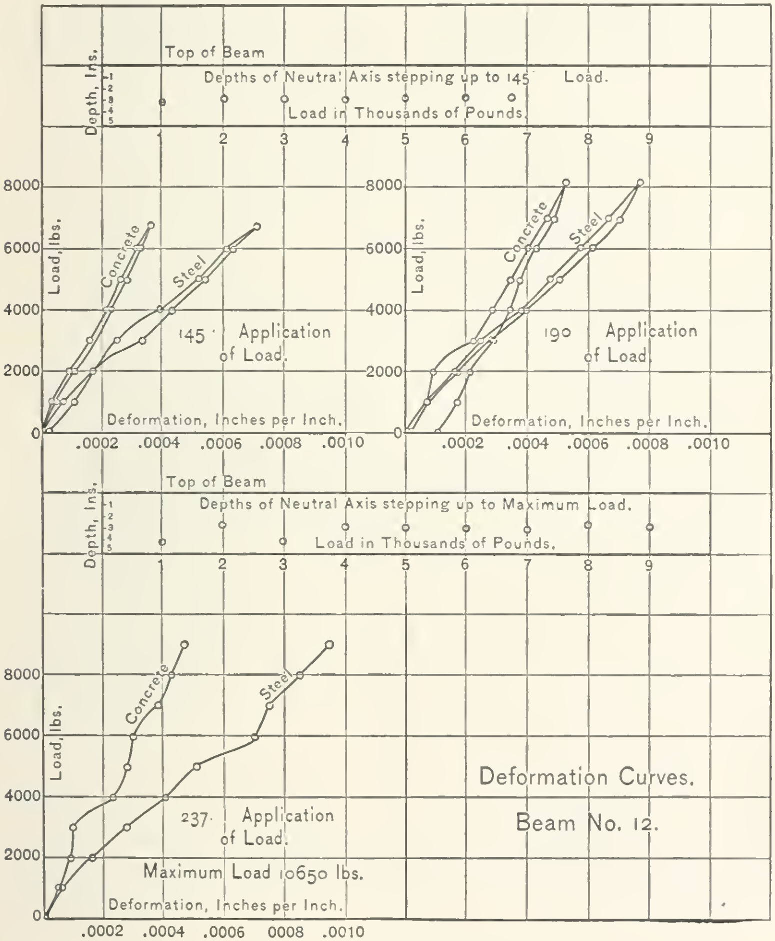


FIG. 4.—Repeated Loading.

was thereby exceeded, and a large crack occurred in the concrete. The test was then interrupted, but will be renewed.

Process 4.—These beams were 8 x 8 inches in cross-section, 7 feet long and tested on a 6-foot span. The reinforcement was one per cent. of soft steel round bars of ordinary surface. In the series (a), the 250-pound weight was dropped on the center of the beam beginning with the 3-inch drop and increasing by 2-inch increments until failure. In series (b), a 100-pound hammer was dropped a large number of times from a constant height of 10 inches.

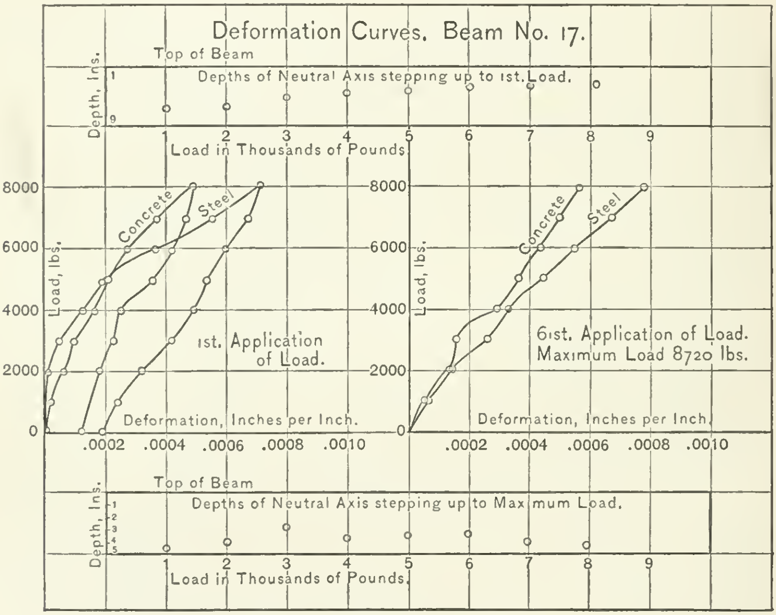


FIG. 5.—Repeated Loading.

In both cases, the deflection and set were recorded for each blow. The machine is described in Vol. VI, p. 462.

RESULTS.

Process 1 *and* 2.—The deflection and the set caused by the process of repeated loadings as compared with the usual process under a continuously applied load are shown in Table I, and illustrated in Figs. 2 and 3, and it will be seen that a stress of 16,000 pounds caused a deflection of 0.14 inches, and that a repetition of loading as shown on Beam 12, increased this deflection to .26 of an inch, and in Beam 15 to .24 of an inch.

There is evidently a continuously increasing deflection and set in beams under this process of repetitive loading. The question as to the source of this set and deflection must be answered by an analysis, which is not at present at hand. The set is, no doubt,

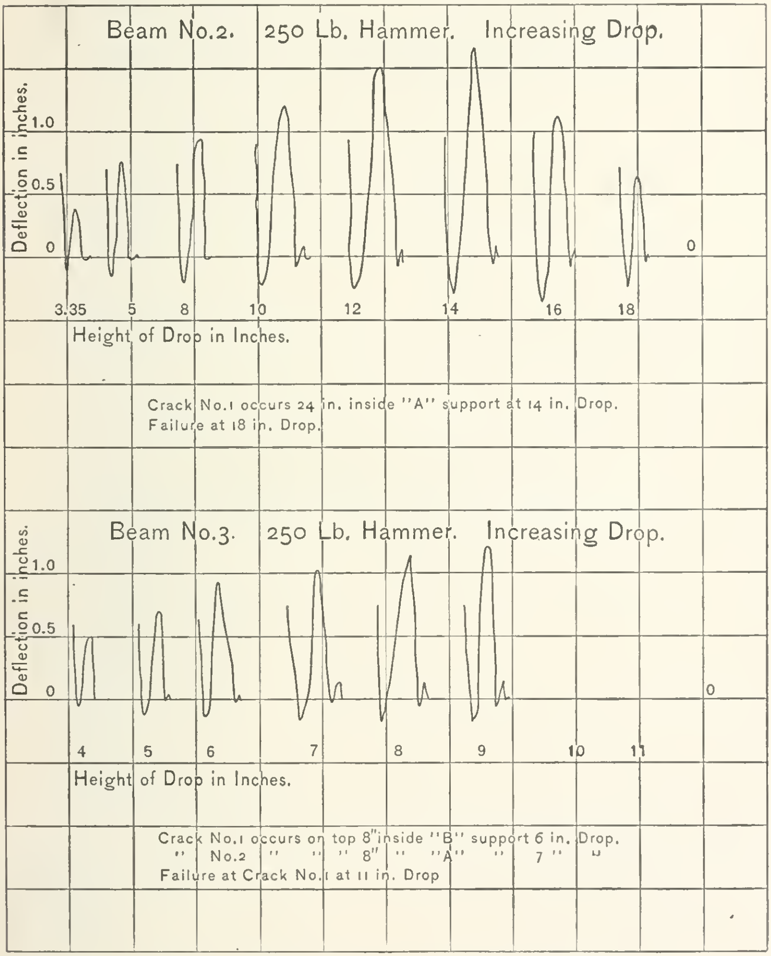


FIG. 6.—Impact Test. Copy of Drum Record.

in both the concrete in compression and the adhesion between the steel and concrete. It is probably more largely in the concrete in compression than in adhesion.

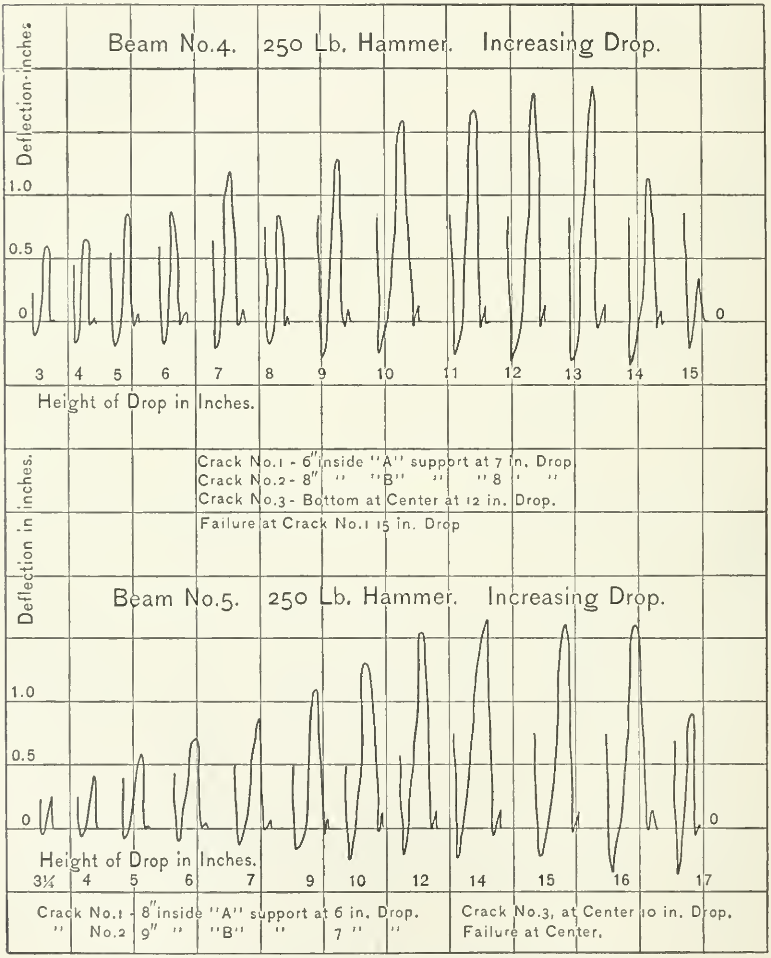


FIG. 7.—Impact Test. Copy of Drum Record.

By reference to Figs. 4 and 5, it will be seen that the process tends to render the ordinary deflection and deformation diagrams more straight than they are under the ordinary loading process. The interesting exhibit in Table II shows that this process of repetitive loading did not diminish the maximum load which the beams carried.

Process 3.—Table I also shows the deflection reached by the beams which were loaded with a constant load for about two months. The deflection, as compared with those under Process 1, have increased very largely. At 16,000 pounds, the increase was about 100 per cent.

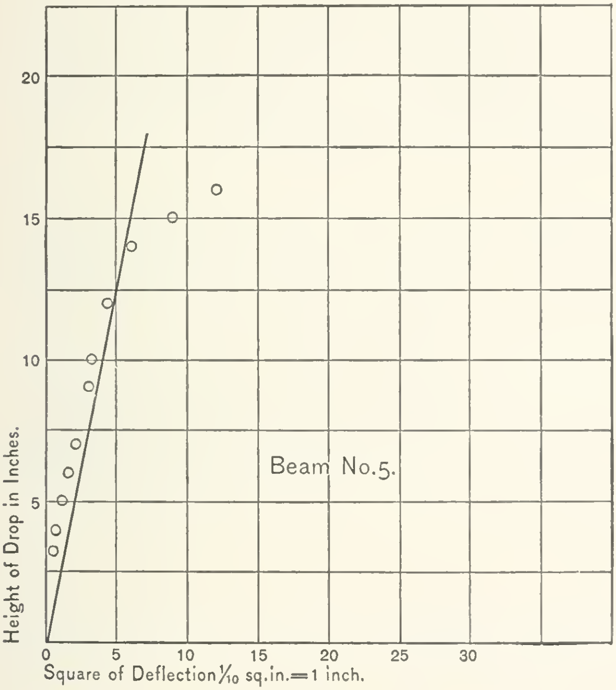


FIG. 8.—Impact Test. Plot from Drum Record.

These results taken together, show a sort of plasticity in concrete, by which it yields under the action of a load applied for a long time, or applied a number of times. The rate of increase of deflection under constant load is shown in Table IV.

Process 4.—These impact tests are to be criticised because the weight of the hammer is too small in proportion to the weight of the concrete beam, and thereby the action was one of vibration as well as of deflection. Local damage of the concrete at the striking point was prevented by a steel plate. The results in Table III are recorded as a matter of interest, rather than of much significance at the present time.

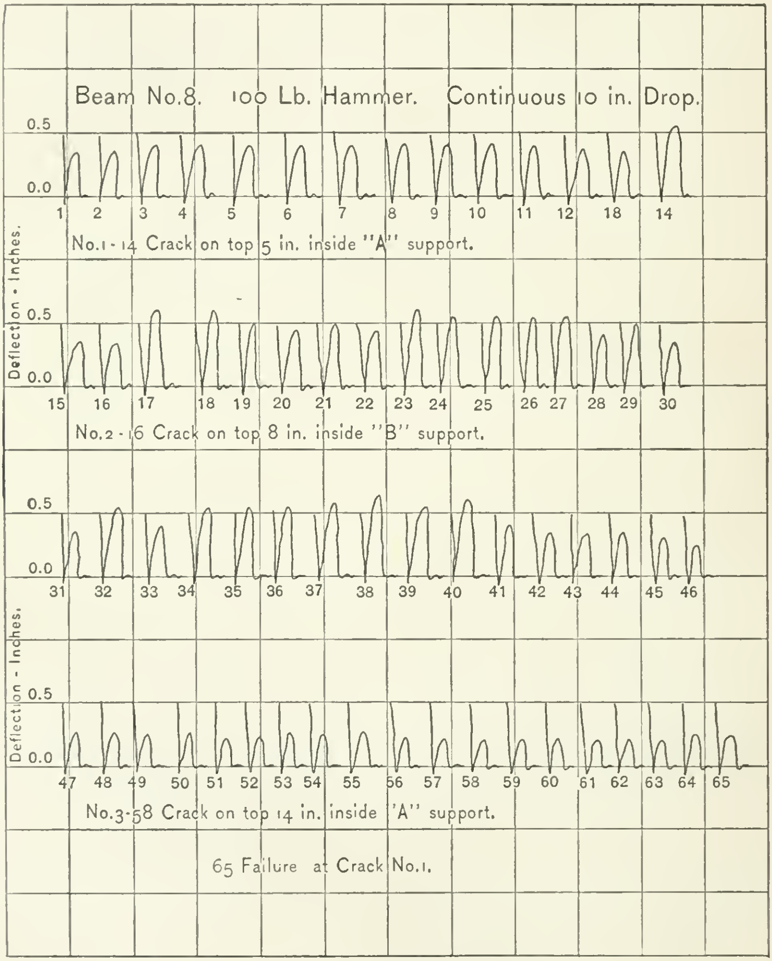


FIG. 9.—Impact Test. Copy of Drum Record.

A curious phenomenon was in the failure which arose in the majority of the beams under the action of the striking weight. The failure was not, as might have been expected, the cracking of the concrete at the center of the beam on the lower side in tension. On the contrary, the first indication of failure was a crack which started at the top of the beam in the compression face some 6 to 24 inches distant from the support. Either this represented a point in the length of the beam where the waves of vibration coincided to produce this crack, or else it may be explained by the inertia of the ends of the beam, which thereby acted to hold the ends while the center was deflecting. In other words, the beams acted to some degree as beams with fixed ends.

The diagrams obtained from impact tests are shown in Figs. 6, 7, 8 and 9.

NOTES ON COLD TWISTED STEEL RODS FOR CONCRETE REINFORCEMENT.

By Jesse J. Shuman.

After several years' experience with the manufacture of cold-twisted steel bars for concrete reinforcement the writer feels that there is not enough definite information on the subject. These notes are published in the hope that they may help engineers to write "safe and sane" specifications to govern the quality of an important material of construction. They may also be of value to those who are called upon to decide on the relative merits of the numerous styles of concrete bars.

Effect of Size.

When a bar is twisted by a machine of the usual type it does not change in length; in fact one end is inserted loosely into the revolving die and there is no tendency to pull out. Hence the central fiber alone is unchanged in length and strength, and the great increase in the strength of the bar is an average of values that are widely different. Moreover, the size of the square has a direct bearing on this average; a point that is commonly neglected in specifications.

If square bars of any size be twisted until they have made one complete turn in 9 times the dimension of a side (pitch = 9), the metal on the corners is stretched about 11.5 per cent. as determined by formulas for helices. The areas of squares, however, vary with the squares of their sides, so that in a small bar the average stretch is greater than in a large bar, and the increase in strength is correspondingly greater. This is amply illustrated by laboratory results in any series of tests in which the size varies, and it should be recognized as a normal manifestation.

Number of Turns.

The moment the twisting machine has created a permanent set in the fiber, the steel has begun to increase in strength, in the same manner as higher yield-point and ultimate strength are set

TABLE I.

EXPERIMENTS WITH ½-INCH TWISTED SQUARES, SHOWING THE EFFECT OF INCREASING NUMBER OF TWISTS.

Grade.	No. of Turns per Foot.	Yield-point. Lbs. per sq. in.			Ultimate Strength. Lbs. per sq. in.			Elongation in 8 in. Per cent.		Reduction of area. Per cent.		Elastic Ratio.	
		Plain.	Twisted.	Increase. Per cent.	Plain.	Twisted.	Increase. Per cent.	Plain.	Twisted.	Plain.	Twisted.	Plain.	Twisted.
Soft Bess.	3	41600	65600	57.7	60400	83200	37.7	28.25	10.0	64.0	49.6	68.9	78.8
"	4¾	39200	72400	84.7	60000	89600	49.3	28.75	5.75	63.4	31.2	65.3	80.8
"	5	41600	84800	103.8	60800	92000	51.3	30.5	6.25	65.8	36.0	68.4	92.2
"	5¾	40800	84000	105.9	60400	90000	49.0	30.0	7.5	64.6	40.0	67.6	93.3
"	5⅞	40000	80800	102.0	60800	88800	46.0	27.5	3.75	60.9	25.2	65.8	91.0
Bess. .25 Carb.	3	48800	83600	71.3	74000	96000	29.7	25.0	8.0	53.8	48.9	65.9	87.1
"	4½	51200	83200	62.5	75200	99200	31.9	25.0	4.5	51.0	46.7	68.1	83.9
"	4⅞	52800	88800	68.2	75200	104000	38.3	24.0	4.0	54.4	44.5	70.2	85.4
"	5	51200	84200	64.4	75600	102000	34.9	22.5	5.75	50.3	44.5	67.7	82.6
"	5½	53200	84200	58.3	75200	100800	34.0	23.0	6.0	51.0	28.6	70.7	83.5
Soft O.H.	3	31200	46000	47.4	46400	64000	37.9	33.0	8.0	74.0	70.8	67.2	71.9
"	5	31200	60800	94.9	47200	68000	44.1	32.5	5.75	68.7	59.0	66.1	89.4
"	7	31200	68800	120.5	46000	76000	65.2	37.5	6.75	73.0	67.0	67.8	90.5
"	9	31200	67200	115.4	47200	71200	50.8	34.0	5.0	74.5	28.6	66.1	94.4

Note: Bars of each grade twisted off when given more turns than here shown.
The "elastic ratio" is the ratio between yield-point and ultimate strength.

up in a bar when it is slightly stretched in a testing machine. As the twisting proceeds the yield-point ascends more rapidly than the ultimate strength. There is a point, however, at which the maximum strength of the bar is reached, and beyond which it is reduced somewhat before the bar twists apart.

The interesting behavior of half-inch squares of three widely different grades is shown in Table I. It would clearly be a mistake to specify a number of turns approaching the maximum strength of the steel, for the internal strains in such a bar are already nearly enough to destroy it; yet it is not uncommon for engineers to do this very thing. In the writer's opinion the number of turns should be about half the number at which the steel is at its maximum strength, and in the ordinary soft Bessemer product this means one complete twist in 8 to 10 times the size of the bar; in other words the pitch of the twist should be 8 to 10 for Bessemer steel of about 60,000 lbs. tensile strength. Basic open-hearth squares of similar grade should have a pitch of 5 to 7 in order to have their best properties developed. If carbons higher than ordinary structural grades are insisted upon, a proportionate concession must be made in the number of twists.

QUALITY.

Excellent results have been obtained with both Bessemer and open-hearth steels of a wide range of carbons. It seems reasonable, however, that the grades that have been found to be best adapted to structural work would also be most reliable for reinforced concrete. Bessemer steel containing carbons up to 0.30 or 0.40 per cent. can be twisted successfully, and are very high in tensile properties, but they have the same brittleness that constitutes the strongest argument against the various hot-rolled and hot-twisted concrete bars. The latter must be high in carbon in order to yield an elastic limit that even approaches that of the soft steel cold-twisted square rods. Surely the lowest yield-point in Table II, in which are shown results on soft Bessemer bars, is high enough to suit the most exacting requirements.

On low-phosphorus steel the effect of twisting is not as marked as on Bessemer steel, the behavior in this respect being quite similar to that of the same steel when cold-rolled or cold-

TABLE II.

TESTS ON PLAIN AND COLD-TWISTED SQUARE BARS, SOFT BESSEMER STEEL.

Number of turns, ordinary.

Size. Inches.	No. of Turns per Foot.	Yield-point. Lbs. per sq. in.			Ultimate Strength. Lbs. per sq. in.			Elongation in 8 in. Per cent.		Reduction of area. Per cent.		Elastic Ratio.	
		Plain.	Twisted.	Increase. Per cent.	Plain.	Twisted.	Increase. Per cent.	Plain.	Twisted.	Plain.	Twisted.	Plain.	Twisted.
¼x¼	4	36800	80000	117.4	65600	92800	41.5	19.5	8.0	64.0	53.8	56.1	86.2
"	4	38400	78400	104.2	68800	91200	32.5	17.5	7.5	64.0	56.5	55.8	86.0
⅜x⅜	3½	39130	71160	81.8	61180	85380	39.5	26.0	10.0	67.8	55.5	63.9	83.3
"	3½	39830	72560	82.2	62330	85380	37.7	28.0	12.0	62.4	60.8	63.9	85.0
½x½	3	41600	65600	57.7	60400	83200	37.7	28.25	10.0	64.0	49.6	68.9	78.8
"	3	38600	66000	71.0	63100	91200	44.5	27.75	10.0	61.7	48.1	61.2	72.4
⅝x⅝	2¼	40020	73860	84.5	63100	85560	35.6	26.0	9.5	63.8	55.6	63.4	86.3
"	2¼	40940	74180	81.2	64640	84960	31.5	28.0	11.0	61.2	56.7	63.3	87.3
¾x¾	1½	40340	74680	85.1	60450	80860	33.8	30.0	13.5	64.0	55.5	66.7	92.4
"	1½	39120	72720	85.9	60080	81060	34.9	31.0	14.0	62.4	58.1	65.1	89.6
⅞x⅞	1¼	39380	71340	81.2	59460	77960	31.1	34.0	13.75	59.2	58.5	66.2	91.5
"	1¼	39640	68700	73.3	59200	75980	28.3	34.0	10.0	61.1	56.3	67.0	90.4
1x1	1	36000	66000	83.3	61000	73900	24.4	32.0	6.5	59.6	43.0	59.0	89.3
"	1	37400	67500	80.5	61000	74000	21.3	33.0	9.0	56.7	53.1	61.3	91.2
1⅛x1⅛	⅞	37550	61640	64.1	58820	70680	20.2	30.0	12.5	60.1	49.3	63.8	87.2
"	⅞	38330	63100	64.6	58820	70580	20.0	31.0	12.5	56.6	50.6	65.0	89.4
1¼x1¼	¾	39530	61100	54.5	61420	78950	28.5	30.0	12.0	47.5	36.0	64.3	77.4
"	¾	38250	62510	63.4	61300	79270	29.3	30.0	6.0	45.2	31.5	62.3	78.8

drawn. The lower results are readily raised, however, by carrying the twisting process further. Table III shows what can be expected of basic open-hearth bars of 55,000 to 65,000 lbs. tensile strength twisted an appropriate number of turns.

Manifestly it would be a poor plan to use open-hearth steel softer than the tests shown in this table, but it would be both safe and advantageous to use steel up to about 0.35 per cent. carbon, with phosphorus under 0.04 per cent.

ELASTIC LIMIT.

Inasmuch as the function of a reinforcing bar is performed inside the elastic limit, the elastic limit is the feature of highest importance from the engineer's standpoint. It is here that the cold-twisted square excels all hot-finished sections and must always continue to do so, for its elastic limit of 60, 70, and even 80 thousand pounds permits the use of less steel for the same service than can be guaranteed by its competitors.

In the testing laboratory it is necessary to take unusual pains to observe the yield-point, commonly called elastic limit, for the reason that the beam of the machine does not always drop when the point is reached at which permanent deformation begins. The machine should be run not faster than $\frac{5}{8}$ inch per minute, and in the absence of an autographic device a pair of dividers should be held on the specimen until the yield-point is observed.

SPECIFICATIONS.

Specifications for cold-twisted bars should be consistent with the behavior of steel of known quality, and should recognize the empirical laws peculiar to the material. Thus, to summarize and add to points made in this paper, the following suggestions are offered as a broad foundation for specifications.

1. Process. Specify whether open-hearth or Bessemer steel is to be used, or either. Open-hearth steel should contain less than 0.04 per cent. phosphorus for basic and 0.06 per cent. for acid steel.

2. Carbon. This should usually be left to the discretion of the manufacturer, who insists that when carbon limits are named the tensile requirements should be left open.

TABLE III.

TESTS ON PLAIN AND COLD-TWISTED STEEL BARS, OPEN-HEARTH OF 55–65,000 LBS. TENSILE STRENGTH.

Number of turns, special.

Size. Inches.	No. of Turns per Foot.	Yield-point. Lbs. per sq. in.			Ultimate Strength. Lbs. per sq. in.			Elongation in 8 in. Per cent.		Reduction of area. Per cent.		Elastic Ratio.	
		Plain.	Twisted.	Increase. Per cent.	Plain.	Twisted.	Increase. Per cent.	Plain.	Twisted.	Plain.	Twisted.	Plain.	Twisted.
½x½	5	38000	58000	52.6	61200	92000	50.3	27.25	5.25	64.0	11.6	62.1	63.0
"	5	37600	60000	59.6	60400	91200	51.0	28.75	5.25	65.2	31.5	62.2	65.8
⅝x⅝	3½	34130	60000	75.8	58660	75450	28.6	27.5	6.25	62.5	55.2	58.2	79.5
"	3½	34880	58480	67.7	58220	76060	30.6	31.25	8.0	61.1	53.7	59.9	76.9
¾x¾	2½	31170	52800	69.4	57020	69670	22.2	31.0	7.5	61.2	46.5	54.7	75.8
"	2½	34370	55770	62.3	57050	69300	21.5	28.75	7.5	59.7	44.8	60.3	80.5
⅞x⅞	2	35660	65960	85.0	60740	78110	28.6	30.0	6.5	60.5	27.6	58.7	84.4
"	2	35000	60870	73.9	59430	71580	20.4	29.0	8.25	50.3	45.7	58.9	85.0
1x1	1¾	33120	57920	74.9	57430	67480	17.5	31.0	9.0	52.5	43.1	57.7	85.8
"	1¾	33360	54350	62.9	59060	72300	22.4	30.75	6.0	54.0	26.8	56.5	75.2
⅛x1⅛	1½	38560	66140	71.5	68760	82560	21.5	32.5	7.75	49.3	14.8	56.0	80.1
"	1½	32350	57290	77.1	56150	72570	29.2	32.25	5.25	60.7	14.6	57.6	78.9
¼x1¼	1½	33740	62230	84.4	55550	68890	24.0	30.0	7.75	46.7	30.7	60.7	90.3
"	1½	32950	57140	73.4	55810	73340	31.4	32.0	6.25	52.0	24.6	59.0	77.9

3. Elastic Limit. For squares $\frac{1}{2}$ in. and smaller, this should be at least 65,000 lbs.; for squares $\frac{5}{8}$ in. to 1 in. at least 60,000 lbs., and for squares $1\frac{1}{8}$ in. and larger at least 55,000 lbs. Manufacturers can generally guarantee minima values somewhat higher than these, but the above would be a reasonable specification.

4. Ultimate Strength. To be recorded.

5. Elongation. At least 5 per cent. in 8 inches, or 12 per cent. in 2 inches.

6. Reduction of Area. To be recorded.

7. Bend. Bar to bend cold around a pin twice its size without distress.

8. Number of Turns. For Bessemer steel, one complete turn in 8 to 10 times the size of the square; for open-hearth steel, in 5 to 7 times the size.

9. Number of Test Pieces. One tension-test specimen and one for bending test for each melt used in each size.

10. Inspection. All tests governing the acceptance of material to be made at manufacturer's works. Inspector to have access to the bars prior to shipment, but the manufacturer is not relieved thereby from responsibility for unsatisfactory material. In this connection it may be stated that each bar is thoroughly cleaned by the twisting process, and that each piece is in a large measure tested at the same time, as no imperfect bar will stand the cold-twisting process.

DISCUSSION.

MR. J. J. SHUMAN.—In the capacity of inspecting engineer at the works of the Jones and Laughlin Steel Company, I found myself some years ago in a position which required me to learn something about a material concerning which I could find nothing written, and the paper that I have presented gives a few points that have come to me through many experiments. It must be taken in the light of a personal report, as I have of necessity had no help from other sources, there being so little available on the subject. It has become apparent to me that the engineers who are using twisted bars for concrete reinforcement are doing so without a very intimate knowledge of the behavior of the material that they are using. I hope the paper may be of some benefit to those who have come to use the material, or are about to use it. It would be easier to get up a paper of this kind in the shape of an advertisement, but I believe I have made it as purely scientific and as little of an advertisement as possible. **Mr. Shuman.**

MR. J. B. FRENCH.—The reading of this paper prompts me to say that as far as my knowledge goes the steel that goes into reinforced concrete is not being tested, and that the purchasers that use it know very little about its properties or quality, and Mr. Shuman being here, he can probably tell us what information he is able to give to purchasers in regard to the physical and chemical properties of the material that is furnished by the Company with which he is connected. **Mr. French.**

It is known that old Bessemer rails are being bought up, twisted hot and furnished to reinforced concrete users, and the people that twist the material cold claim that the hot twisted material is very unreliable, because the phosphorus is excessive, and that it is liable to break and crack in using.

Having myself insisted on cold-twisted material, made tests of it and failed to make it bend more than 45° without breaking off short, I have been forced to think that the claims in favor of the cold-twisted material (made from Bessemer stock) may sometimes be very misleading.

Mr. French. If we go back to the manufacturer and ask him for the best information he can furnish us in regard to Bessemer steel that is put into rods for cold-twisting, he gives us what he calls an "*average*" analysis. We are not able to find out the extremes between which the results vary, but must be satisfied with the "average." If we try to go a little further and find out how often analyses are made, we are told that an analysis every three or four blows is all that can be furnished.

I think that in view of the many important uses to which reinforced concrete is now being put, and the failures, many of them involving the loss of human life, which often result from the use of bad material, that steel for the reinforcement of concrete should be as carefully specified, inspected and tested as is considered necessary for structural steel used in bridges and buildings, and if this view is correct, Bessemer steel will be excluded from use in reinforced concrete structures exactly as is already done in the case of important structures built entirely of steel.

Mr. Shuman. MR. SHUMAN.—I will make my reply just as brief as I can and at the same time cover the points that have been mentioned.

It was not my intention to bring about a comparison between cold-twisted squares and hot-twisted squares; because if any one is sufficiently interested in the subject to make comparative tests he will note the difference at once. The simple test that I have suggested here, requiring a bar to stand cold-bending around a pin twice its own size, would be enough to reject almost any hot-twisted bar if made out of high-carbon Bessemer steel. Moreover, the elastic limit of cold-twisted rods is so high that it cannot be reached by any of the hot-finished sections; and if the latter are made in carbons high enough to approach this elastic limit the steel is of necessity brittle and treacherous.

As to phosphorus, it is true that no Bessemer steel works determines the phosphorus on every heat; that would be not only out of the question, but it would be useless, for phosphorus is very nearly a constant in Bessemer practice. The feature that concerns the user of a cold-twisted bar or any other bar is not how much phosphorus there is in the steel, but what it will stand under given physical tests. I believe if these specifications (which are very broad) are followed, the product will be sure to give satisfaction. It is not out of the question, however, for a steel works to supply the

Mr. Shuman. analysis of every Bessemer blow that goes into its products, with the exception of phosphorus. The carbon manganese and sulphur can always be given in any well regulated plant. All four elements are determined in standard open-hearth practice.

Mr. French. MR. FRENCH.—That simply confirms my statement, that as far as Bessemer material is concerned (just as brought out in regard to steel rails the other day), the testing is a purely haphazard matter; that is, we do not definitely know what each test represents. The particular blow represented is all right; but the material that was rolled from that blow is not identified.

As far as the statement goes that these average analyses, or these analyses of occasional heats or blows, represent uniform conditions, I know, as a matter of fact, from check analyses that have been made within the last two or three months, that we found as high as 13 and 14 points of phosphorus in samples taken from material represented to show less than 10 points, and we have found bars that break before being bent to 90°.

Mr. Woolson. MR. IRA H. WOOLSON.—Apropos of this, I might state that this past week we made in my laboratory some tests upon some twisted bars furnished by one of the city departments; these bars were said to be cold-twisted and annealed. They gave 100,000 pounds per square inch ultimate; about 63,000 for yield point; about 18 to 20 per cent. elongation; and reduction varying from 29 to 49 per cent. The elongation being high for that grade of steel, there was some question raised in regard to it, and analyses were made. Upon three of the six samples tested we found they ran about 0.50 carbon, and about 0.10 to 0.13 phosphorus. It seemed to me those were rather remarkable results for that kind of material. They were said to be cold-rolled, but I have no reliable information regarding the process of manufacture.

Mr. Quimby. MR. H. H. QUIMBY.—The Philadelphia Bureau of Surveys prescribes a standard grade of material for all structural work, the same for reinforced bars as for bridge material and open-hearth always. The grade is that fixed by the specifications adopted by this Society, 60,000 pounds mean ultimate. It seems hardly fair when we prescribe the grade of the plain material as these specifications propose, to then prescribe definite subsequent treatment such as cold-twisting, and require the manufacturer to guarantee a certain effect of that treatment. We prescribe that

Mr. Quimby. if the bar is twisted, it shall be twisted cold. Our grade of steel stands twisting cold, stretching in tensile test, and bending double close, three operations on the same piece, although each operation stretches the extreme fibers beyond the elastic limit. We have been prescribing one complete turn in eight diameters, but will hereafter require one turn in six diameters. We have found the effect of twisting to be an increase of ultimate strength of about 50 per cent. The specifications proposed in this paper seem to me to form merely a part of a general scheme, and I would criticize them only to the extent that the effect of the twisting should not be prescribed, and that the elastic limit should not be limited. It seems to me that the difficulty of determining the yield point of the twisted specimen is so great that it constitutes another reason for not prescribing the elastic limit in twisted bars.

TESTS OF BOND BETWEEN STEEL AND CONCRETE.

By T. L. Condron.

About a year ago the writer began investigating the relative strength of bond between concrete and different forms of steel bars. In his study of published tests he found no reports that took account of a progressive slipping of bars in concrete with increase of load. The reports of bond tests gave only the maximum loads required to pull out of the concrete bars embedded in different lengths. In order to investigate the subject further, the writer had about 30 specimens of bars embedded in concrete cylinders 12 inches long. The specimens included plain round and plain square, cold twisted, hot twisted and Johnson corrugated bars. The concrete was the regular mixture that was being used in the floors of the Pioneer Paper Stock Company's building in Chicago, and the specimens were made by the contractor on this building. Each concrete cylinder was cast upon a cast iron base plate as shown in Fig. 1. In order to test these specimens it was necessary to send them to a laboratory, and the nearest laboratory was that of the Lewis Institute, Chicago, which is located about one and a half miles from the Pioneer Building. The specimens when about two weeks old were carefully packed in hay and hauled in an ordinary express wagon to the laboratory. Prof. C. E. DePuy made the tests when the specimens were six weeks old. The apparatus used for measuring the movement, or slip, of the bars is clearly shown in Fig. 1. The results of these tests were rather erratic, due in part, probably to the jarring that the specimens received in hauling to the laboratory. However, it is interesting to see what the results of these first tests were. The results are shown graphically in Fig. 2.

After getting the results of these first tests from Prof. DePuy, the writer decided to continue the investigation and to eliminate the disturbance and possible injury of specimens due to cartage, by having the specimens made up in the laboratory where they could remain until tested. He, therefore, arranged with Prof. DePuy to make a second set of tests under more exact and scientific conditions. The results of this second set of tests is given in a report by Prof. DePuy, from which the following is taken:*

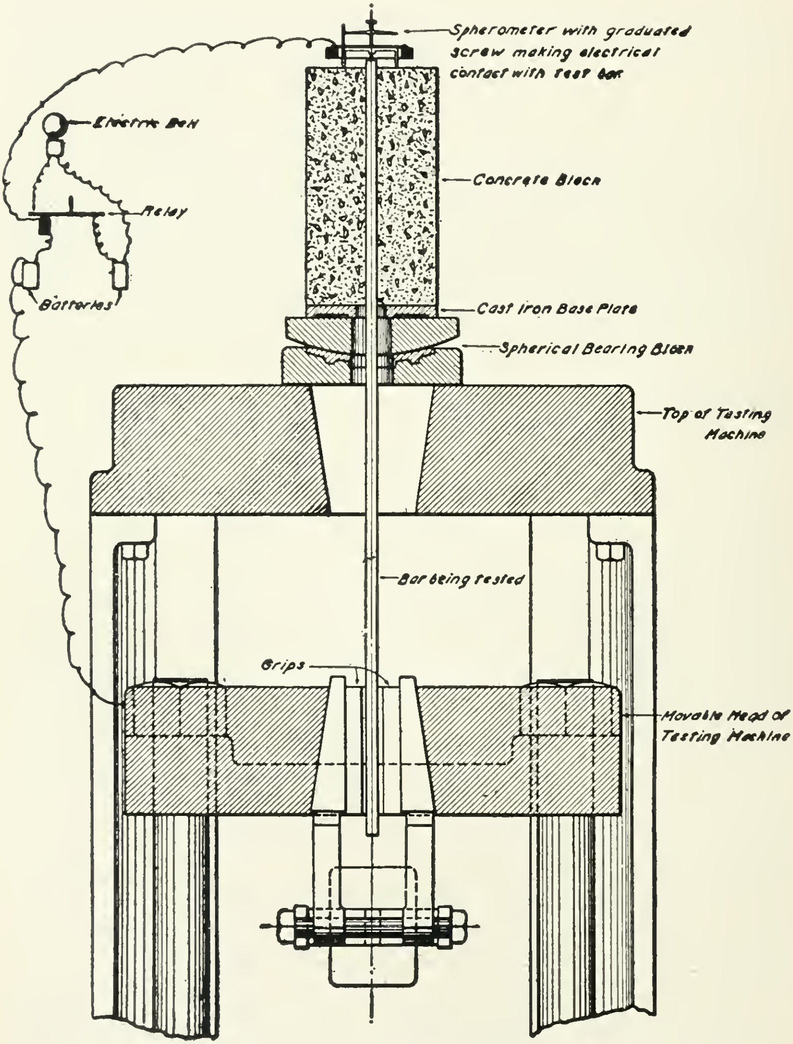


FIG. 1.—Apparatus for Testing Bond Between Concrete and Steel.

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* *Journal Western Society of Engineers*, Chicago, Vol. XII, No. 1, 1907.

The object in making these tests was to determine the relative strength of bond between concrete and steel for different shaped bars, when the quality of concrete was uniform and the lengths of embedment the same for each of the several different kinds of bars. Also to measure the amount of slip, as well as the loads or stresses causing the slips.

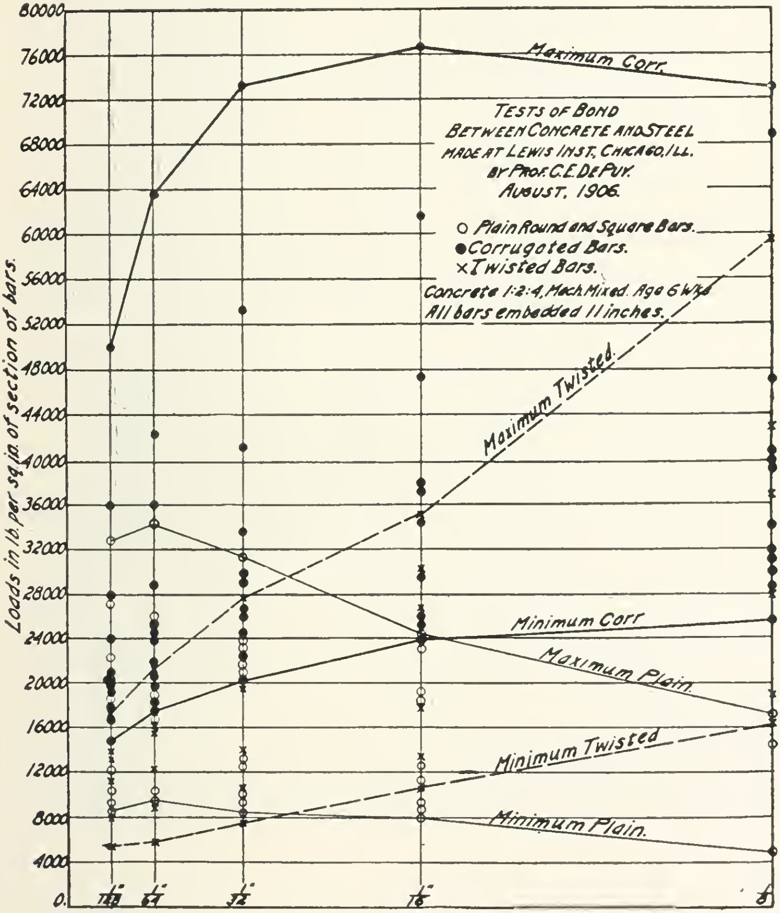

FIG. 2.—Showing the Slipping of Bars as Loads were Applied.

In order to make the results comparable bars were secured for the tests having as nearly as possible the same average area of cross section and weight per foot as shown in Table I. There were seven kinds of bars tested and five lengths of embedment of each kind. The lengths of embedment were 8, 12, 16, 20 and 24 inches for each kind of bar.

TABLE I.—DESCRIPTION OF BARS USED IN TESTS.

Bars.	Size. Inches.	Weight per foot. Pounds.	Average Area. Sq. in.	Average Perimeter. Inches.
Round	$\frac{11}{16}$	1.284	.378	2.17
Square	$\frac{5}{8}$	1.322	.390	2.50
Twisted (B) *	$\frac{5}{8}$	1.343	.395	2.51
Twisted (R) †	$\frac{5}{8}$	1.345	.395	2.51
Thacher	$\frac{3}{4}$	1.310	.385	....
Corrugated (N) ‡	$\frac{5}{8}$	1.250	.368	2.43
Corrugated (O) §	$\frac{3}{4}$	1.443	.424	2.60

The apparatus used is clearly indicated in Fig. 1. The concrete blocks were cylindrical with a diameter of 6 inches and 8, 12, 16, 20 and 24 inches long. Each concrete block had a cast iron base plate, turned to a true face. These blocks were supported upon a spherical bearing block on the top of an Olsen testing machine so that the specimen could be properly adjusted for a direct pull on the bars. The lower projecting end of the bar was gripped into the movable head of the testing machine. The upper end of the bar projected $\frac{3}{4}$ of an inch above the top of the block, while upon the concrete block rested a spherometer with the graduated screw brought into contact with the upper end of the bar being tested, thus closing an electric circuit. As the load came on, the slightest slipping of the bar in the concrete would break the electric circuit, causing a bell to ring until the graduated screw was turned down and the circuit closed. By this means it was possible to measure very accurately the movement of the bars and the load causing the same.

The concrete was hand mixed with great care after the proportions had been accurately measured. The mixture was one Atlas Portland cement, two coarse sand and four broken limestone, of $\frac{1}{2}$ inch and under, without dust. This was mixed to a fairly wet concrete, one that would easily enter the molds and could be churned readily with a small iron rod. All the concrete used was mixed in one batch. The sheet iron forms in which the blocks were molded were removed about one week before testing. The tests were made when the concrete was 25 days old for the 8 and 16 inch embedments, and when the concrete was 31 days old for the 12, 20 and 24 inch embedments

RESULTS OF TESTS.

The results obtained are graphically shown in Figs. 3 and 4 and tabulated in Tables II and III. These diagrams show the results of

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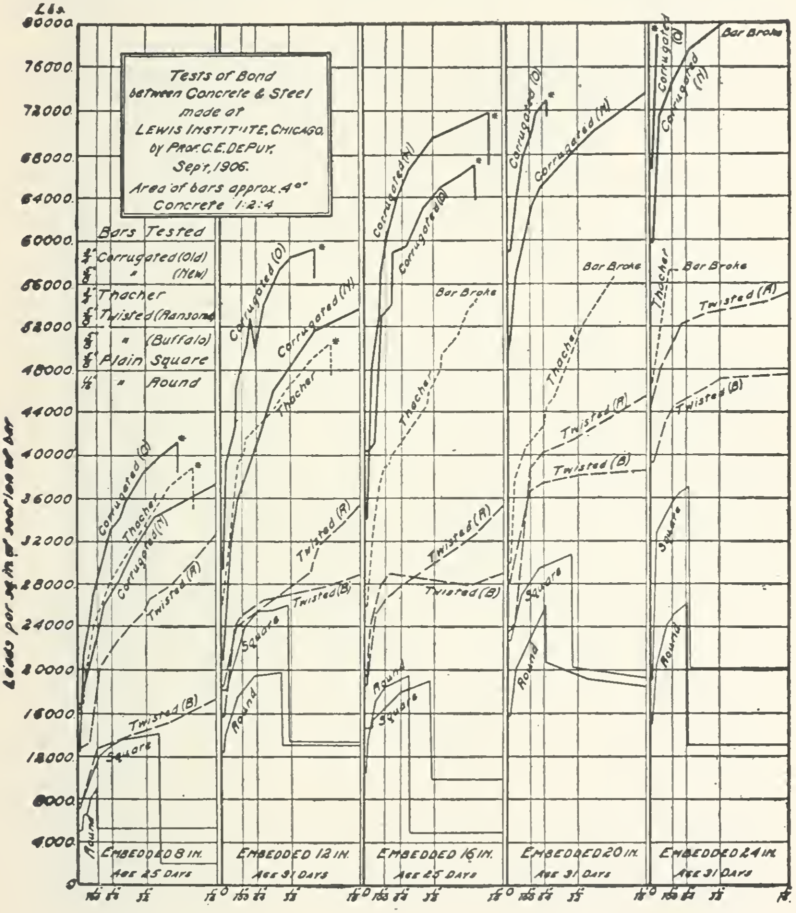
* Buffalo Steel Company, 2.3 twists per foot.

† Ransome, 2.8 twists per foot.

‡ New Style.

§ Old Style.

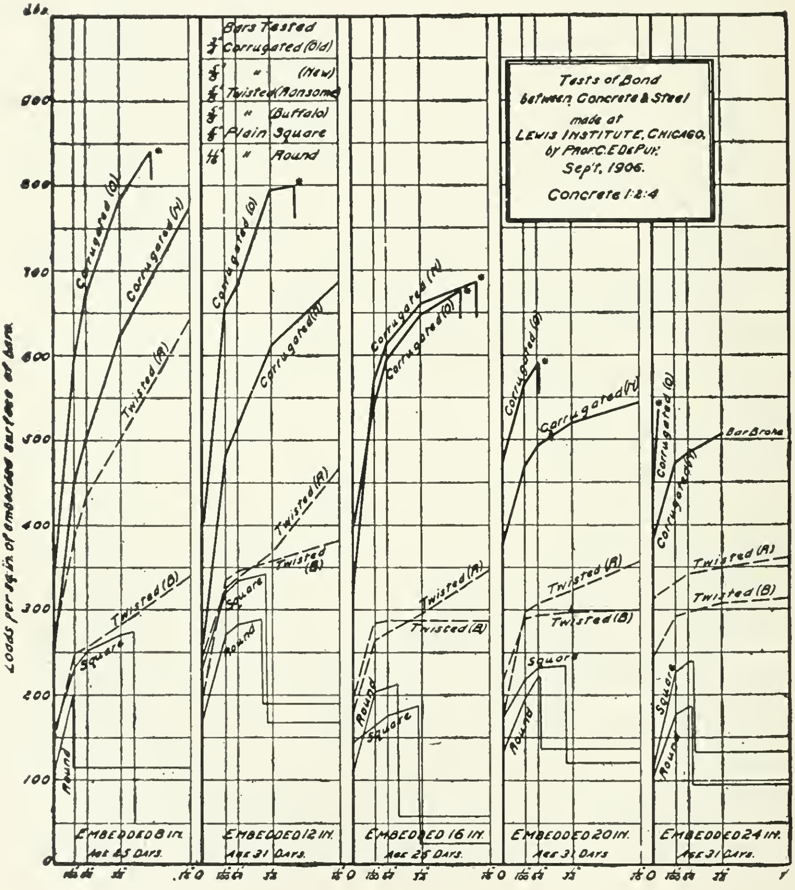
all the tests, with a maximum slip of $\frac{1}{16}$ of an ich. Where the maximum load or stress on the bar was not reached within a slip of $\frac{1}{16}$ of an inch, the



*Concrete Split.

FIG. 3.—Results of Tests of Bond of Seven Kinds of Bars and Five Lengths of Embedment, Ranging from 12 to 38 Diameters. Loads in Lbs. per Sq. In. of Section Areas of Bars, and Slips in Fractions of an Inch.

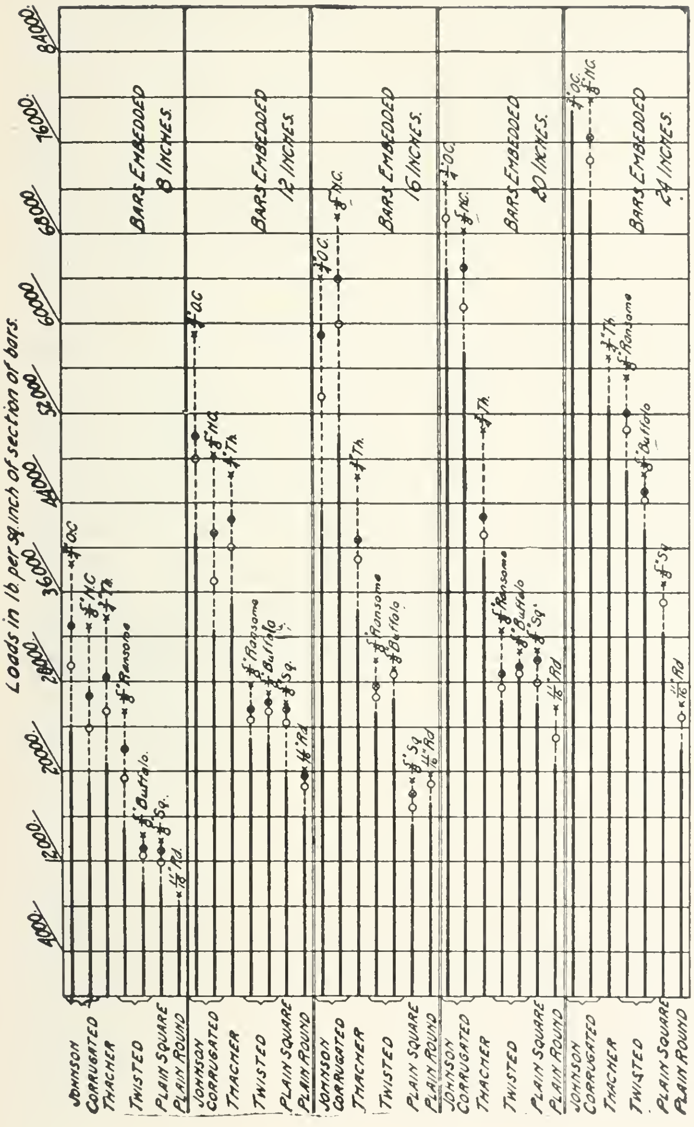
curves would extend beyond the limits of these diagrams. In Fig. 3 the stresses or pulls on the bars are reduced to pounds per square inch of the cross sections of the bars, while in Fig. 4 these stresses or pulls on the bars are reduced to pounds per square inch of the embedded surface of the bars. In Table II and III the actual stresses on the bars with the corresponding slips are given, first in pounds per square inch of section of the bars, and



*Concrete Split

FIG. 4.—Results of Tests of Bond of Seven Kinds of Bars and Five Lengths of Embedment Ranging from 12 to 38 Diameters. Loads in Lbs. Per Sq. In. of Embedded Surface of Bars and Slips in Fractions of an Inch.

second in pounds per square inch of the embedded surface of the bars. As there was no way of readily determining the surface areas of the Thacher bars, these are not included in Fig. 4 and Table III.



Relative Efficiencies of Bond of Different Bars

Full Lines indicate maximum load when slip was not over 1/250 inch; ○ 1/16 inch; ⊗ 1/64 inch; × 1/32 inch.

FIG. 5.

TABLE II.—RESULTS OF BOND TESTS.

Stresses on bars in pounds per square inch of cross section.

Embedment.	8 in.	12 in.	16 in.	20 in.	24 in.
Slip not more than $\frac{1}{100}$ inch.					
Round	9,200	18,700	18,900	23,000	24,800
Square	11,900	24,300	16,800	28,000	35,200
Twisted (B)	12,700	25,400	28,800	36,500	44,300
Twisted (R)	19,400	24,600	26,000	38,300	50,600
Thacher	25,300	40,800	38,900	41,200	57,100
Corrugated (N)	23,800	37,500	60,000	61,500	74,500
Corrugated (O)	29,200	48,000	53,500	69,400	79,000
Slip not more than $\frac{1}{32}$ inch.					
Round	*9,200	*20,100	*19,800	*26,000	*26,500
Square	13,900	*26,200	*19,300	*30,800	*37,300
Twisted (B)	14,400	27,100	29,100	37,900	46,700
Twisted (R)	25,400	27,800	30,000	41,700	53,400
Thacher	33,800	46,600	46,400	50,600	*57,100
Corrugated (N)	33,000	48,400	69,600	68,400	*80,000
Corrugated (O)	38,500	58,000	64,100	*73,700	*79,000

The relative efficiencies of bond of the different bars tested may be seen at a glance by reference to Fig. 5. The maximum stresses which the bars withstood without slipping at all, or with a slip not exceeding $\frac{1}{200}$ of an inch, are indicated by the lengths of the full lines on this diagram, for each length of embedment. Likewise the stresses causing the bars to slip $\frac{1}{100}$ in., $\frac{1}{64}$ in., and $\frac{1}{32}$ in. are shown:

TABLE III.—RESULTS OF BOND TESTS.

Stresses on bars in pounds per square inch of embedded surface of bars.

Embedment.	8 in.	12 in.	16 in.	20 in.	24 in.	Average.
Slip not over $\frac{1}{100}$ of an inch.						
Round	198	269	203	198	178	209
Square	232	316	164	218	229	232
Twisted (B)	250	334	283	288	291	289
Twisted (R)	382	324	256	312	332	321
Corrugated (N)	452	474	569	467	471	487
Corrugated (O)	594	651	545	565	535	578

* Developed full strength of bond before slipping $\frac{1}{32}$ inch.

TABLE III.—RESULTS OF BOND TESTS (Continued).

Embedment.	8 in.	12 in.	16 in.	20 in.	24 in.	Average.
Slip not over $\frac{1}{32}$ of an inch.						
Round	*198	*289	*214	*224	*190	223
Square	271	*341	*188	*240	*242	256
Twisted (B)	283	357	287	299	306	306
Twisted (R)	500	366	295	329	350	368
Corrugated (N)	626	612	660	519	506	585
Corrugated (O)	784	786	653	593	535	670

Since the tests made by Prof. C. E. DePuy in September, 1906, the writer has had a further series of bond tests made by Prof. DePuy, with the same apparatus. In this latest series the bars tested are given in Table IV:

TABLE IV.—DESCRIPTION OF BARS USED IN TESTS, JUNE, 1907.

Bars.		Weight per foot. Pounds.	Average area section. Sq. in.	Average area of surface embedded. Sq. in.		
Size. Inches.	Kind.			12 in.	16 in.	24 in.
$\frac{11}{16}$	Round	1.284	.378	26.1	....	52.3
$\frac{5}{8}$	Square	1.322	.386	29.8	....	59.6
$\frac{3}{4}$	Old Style Corr.	1.504	.442	31.9	....	63.8
$\frac{5}{8}$	New Style Corr.	1.292	.380	29.6	....	59.2
$\frac{1}{2}$	New Style Corr.	0.850	.250	24.0	....	48.0
$\frac{1}{2}$	Old Style Corr.	0.70	.206	21.6	....	43.2
2 x $\frac{3}{8}$	Universal	2.05	.603	50.0	66.7	100.0
$1\frac{1}{4}$ x $\frac{1}{4}$	Universal	.975	.287	36.0	48.0	72.0
$\frac{3}{4}$	Lug	1.975	.582	36.6	48.8	73.2
$\frac{5}{8}$	Lug	1.40	.412	30.8	....	61.6
$\frac{5}{8}$	Diamond	1.391	.410	27.2	....	54.2

These bars were embedded 12 inches and 24 inches, except that three specimens were embedded 16 inches. The concrete was of the same proportion, 1 : 2 : 4, and the same kind of sand and stone were used as in the former series, but Lehigh cement was used instead of Atlas. All of the specimens were left in the sheet iron forms for two days when the forms were removed and those marked "D" were allowed to age in air in the basement until tested, while

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* Developed full strength of bond before slipping $\frac{1}{32}$ inch.

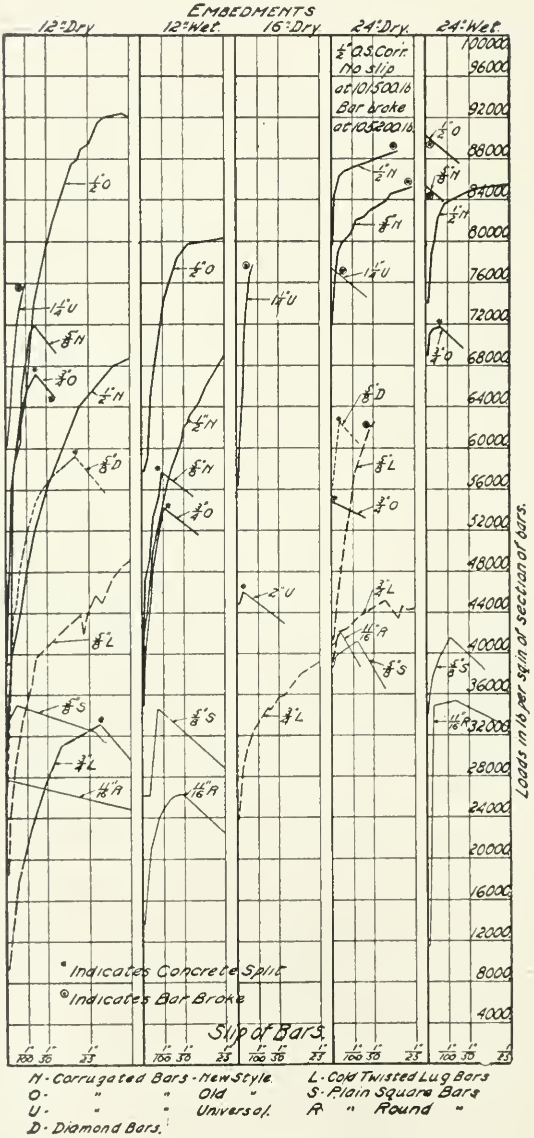

EMBEDMENTS
12" Dry
12" Wet.
16" Dry
24" Dry.
24" Wet.
½" O.S. Corr. No slip at 101500 lb Bar broke at 105200 lb
½" O
1¼" U
⅝" N
¾" O
½" N
⅝" D
⅝" L
⅝" S
¾" L
11/16" R
2" U
• Indicates Concrete Split
⊙ Indicates Bar Broke
Slip of Bars.
1"/100
1"/50
1"/25
100000
96000
92000
88000
84000
80000
76000
72000
68000
64000
60000
56000
52000
48000
44000
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
Loads in lb per sq in of section of bars.
N - Corrugated Bars - New Style.
O - " " Old "
U - " " Universal.
D - Diamond Bars.
L - Cold Twisted Lug Bars
S - Plain Square Bars
R " Round "

FIG. 6.

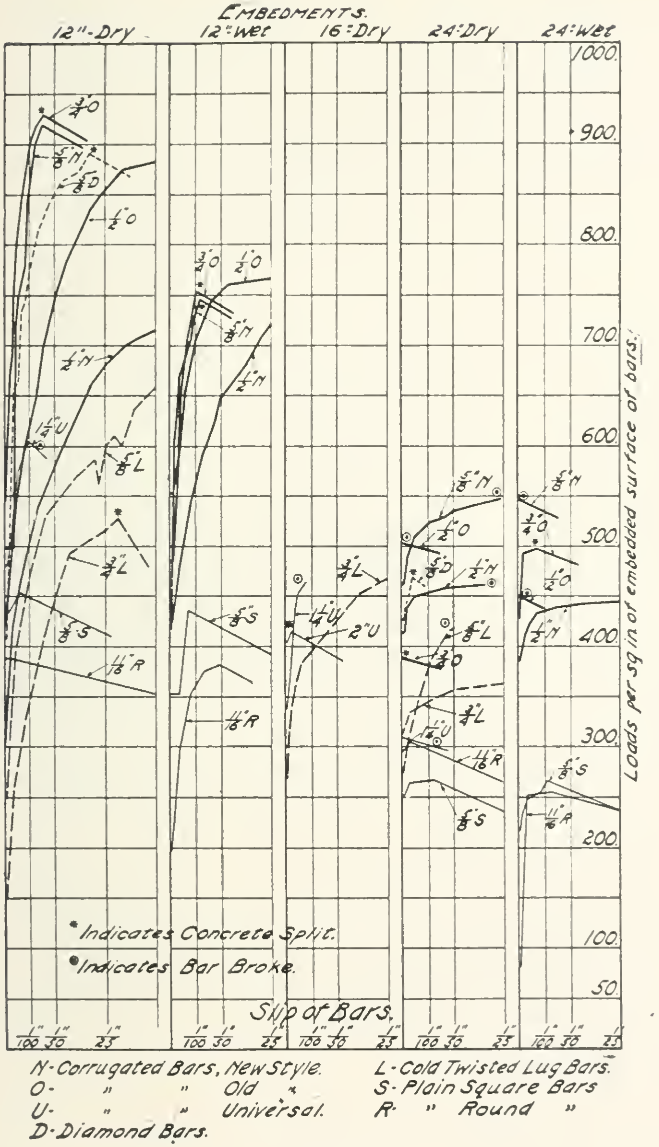

EMBEDMENTS.
12"-Dry
12"-Wet
16"-Dry
24"-Dry
24"-Wet
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
50.
Loads per sq in of embedded surface of bars.
Slip of Bars.
1"/100 1"/50 1"/25
* Indicates Concrete Split.
⊙ Indicates Bar Broke.
3/4" O
5/8" N
5/8" D
1/2" O
1/2" N
1 1/4" U
5/8" L
3/4" L
5/8" S
11/16" R
2" U
N - Corrugated Bars, New Style.
O - " " Old "
U - " " Universal.
D - Diamond Bars.
L - Cold Twisted Lug Bars.
S - Plain Square Bars
R - " Round "

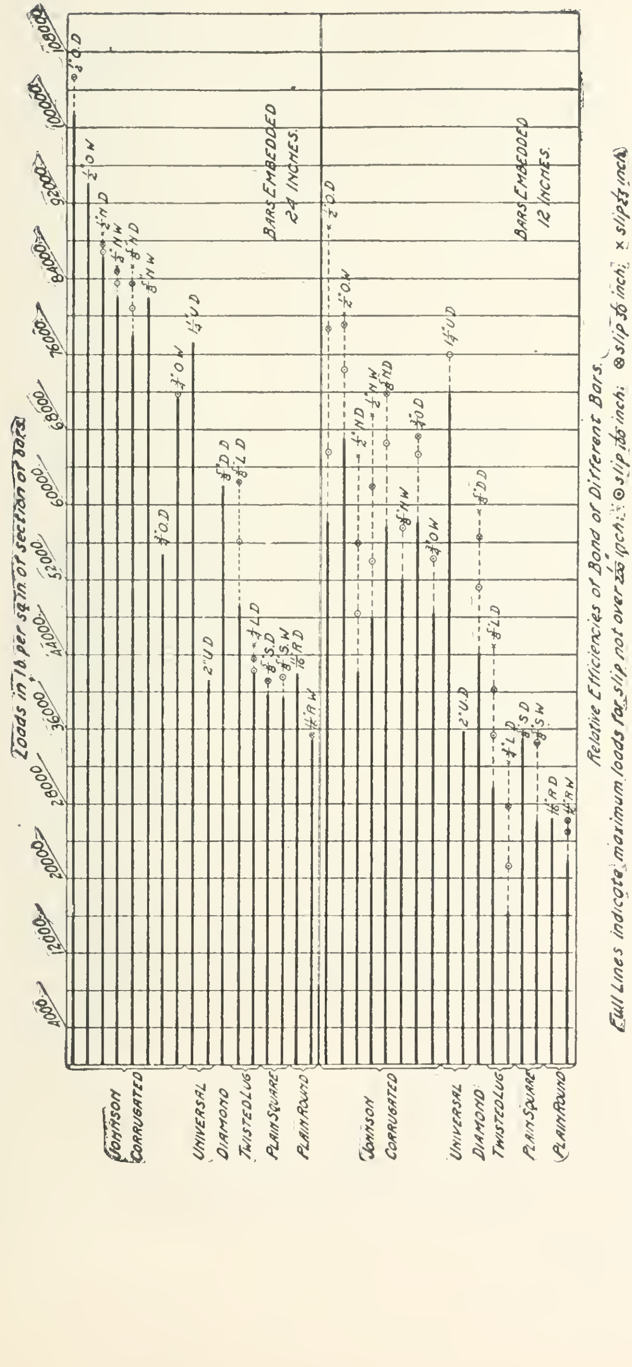
FIG. 7.

the specimens marked "W" were immersed in water until the day before they were tested. Those marked "D" were tested when 28 days old and those marked "W" were 35 days old when tested. The results of the tests are given in Tables V to VIII inclusive and shown graphically in Figs. 6 and 7. The latter show clearly the progressive slipping of the bars as the loads were applied; also the difference between the specimens kept under water and those kept in air. It is unfortunate perhaps that it was not convenient to make all of these tests when the concrete was of the same age, as the "wet" specimens were 35 days old and the "dry" specimens were 28 days old.

In these latest tests it is evident that the concrete was somewhat stronger than in the earlier tests, but the relative strength of bond between the different kinds of bars remains about the same. In Fig. 8 are shown the relative efficiencies of the different bars in these latest tests. This diagram is similar to Fig. 5 previously referred to. In this figure the lengths of the full lines indicate the maximum stresses the bars withstood without slipping more than $\frac{1}{200}$ of an inch. The stresses producing slips of a greater amount up to $\frac{1}{25}$ of an inch are also indicated. The "wet" and "dry" specimens are shown one under the other in each case, so that a ready comparison can be made. While the "wet" specimens were allowed to remain under water for 33 days, they generally developed a lower bond strength. The difference is not very marked, except in the case of the plain bars. In Figs. 6 and 7 these differences in plain bars are clearly shown, and it would appear that the immersion of concrete had a marked effect on bond strength for plain bars.

As would be expected, the form of the twisted lug bar is not such as to materially increase the bond value of this bar over plain bars; in fact as shown in the diagrams, these bars began to slip in the concrete under less stress than the plain bars. The lugs are not of sufficient size to be effective, and the twisting introduces a wedging action in the concrete rather than a direct compressive or shearing action.

The bond value of the Diamond bar specimens approached more nearly to that of the corrugated bars, and in the 12 in. embedment the Diamond bar developed about the same strength of bond as the ½ in. new section corrugated.



Relative Efficiencies of Bond of Different Bars.

Full Lines indicate maximum loads for slip not over 1/100 inch: ⊙ slip 1/100 inch: ⊗ slip 1/50 inch: × slip 1/25 inch.

FIG. 8.

TABLE V.—MAXIMUM LOADS ON BARS IN POUNDS PER SQUARE INCH OF SECTION WHEN SLIP DID NOT EXCEED THAT NOTED.

Specimens kept in air. (Age, 28 days.)

Size and kind of bar. Inches.	12-INCH EMBEDMENT.—DRY.				16-INCH EMBEDMENT.—DRY.				24-INCH EMBEDMENT.—DRY.			
	Slip in inches.				Slip in inches.				Slip in inches.			
	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$
$1\frac{1}{16}$ Round	*26,700	....	....	....	....	....	....	....	*42,100	....	....	....
$\frac{5}{8}$ Square	35,000	....	....	....	....	....	....	....	39,900	39,900	*41,200	....
$\frac{3}{4}$ Lug	16,500	21,500	27,800	32,600	30,800	33,200	35,600	*39,400	42,000	42,400	43,700	45,200
$\frac{5}{8}$ Lug	29,900	35,400	40,300	45,000	....	....	....	....	49,300	56,100	*62,400	....
$\frac{5}{8}$ Diamond	44,100	51,200	56,600	*59,300	....	....	....	....	*62,000	....	....	....
2 x $\frac{3}{8}$ Universal	†35,800	....	....	....	*46,000	....	....	....	‡9,950	....	....	....
$1\frac{1}{4}$ x $\frac{1}{4}$ Universal	71,900	*76,000	....	....	72,900	*77,700	....	....	*77,400	....	....	....
$\frac{3}{4}$ O. S. Corr.	58,200	65,400	*67,300	....	....	....	....	....	*54,800	....	....	....
$\frac{5}{8}$ N. S. Corr.	57,900	66,500	*71,800	....	....	....	....	....	78,200	80,800	83,500	*85,300
$\frac{1}{2}$ N. S. Corr.	42,400	48,400	56,000	65,200	....	....	....	....	86,400	86,800	87,600	*88,800
$\frac{1}{2}$ O. S. Corr.	58,300	65,600	78,600	89,400	....	....	....	....	*101,500	....	....	....

* Maximum loads. † Maximum load was 37,500. ‡ Maximum load was 41,300.

TABLE VI.—MAXIMUM LOADS ON BARS IN POUNDS PER SQUARE INCH OF SECTION OF BAR WHEN SLIP DID NOT EXCEED THAT NOTED.

Specimens kept in water. (Age, 35 days.)

Size and kind of bar. Inches.	12-INCH EMBEDMENT.—DRY.				16-INCH EMBEDMENT.—DRY.				24-INCH EMBEDMENT.—DRY.			
	Slip in inches.				Slip in inches.				Slip in inches.			
	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$
$\frac{11}{16}$ Round.........	22,000	25,100	*26,400	....	....	....	....	....	34,900	35,200	*35,400	....
$\frac{5}{8}$ Square.........	26,200	*34,700	....	....	....	....	....	....	39,500	*41,600	....	....
$\frac{3}{4}$ O. S. Corr.......	48,600	*54,300	....	....	....	....	....	....	71,500	*71,800	....	....
$\frac{5}{8}$ N. S. Corr.......	52,100	*57,600	....	....	....	....	....	....	*85,300	....	....	....
$\frac{1}{2}$ N. S. Corr.......	48,000	54,000	62,000	69,600	....	....	....	....	82,000	83,600	84,800	85,200
$\frac{1}{2}$ O. S. Corr.......	67,000	74,300	79,100	80,100	....	....	....	....	*94,200	....	....	....

* Maximum loads.

TABLE VII.—MAXIMUM LOADS ON BARS IN POUNDS PER SQUARE INCH OF EMBEDDED SURFACE WHEN SLIP DID NOT EXCEED THAT NOTED.

Specimens kept in air. (Age, 28 days.)

Size and kind of bar. Inches.	12-INCH EMBEDMENT.—DRY.				16-INCH EMBEDMENT.—DRY				24-INCH EMBEDMENT.—DRY.			
	Slip in inches.				Slip in inches.				Slip in inches.			
	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$
$\frac{11}{16}$ Round	*387	....	....	....	....	....	....	....	*304	....	....	....
$\frac{5}{8}$ Square	*453	....	....	....	....	....	....	....	265	265	*267	....
$\frac{3}{4}$ Lug	262	342	443	*527	367	396	425	451	334	338	356	360
$\frac{5}{8}$ Lug	400	451	542	600	....	....	....	....	330	375	*418	....
$\frac{5}{8}$ Diamond	665	771	852	*892	....	....	....	....	*469	....	....	....
2 x $\frac{3}{8}$ Universal	†432	....	....	....	*415	....	....	....	‡60	....	....	....
1 $\frac{1}{4}$ x $\frac{1}{4}$ Universal	523	*606	....	....	436	*465	....	....	*308	....	....	....
$\frac{3}{4}$ O. S. Corr	805	906	*930	....	....	....	....	....	*389	....	....	....
$\frac{5}{8}$ N. S. Corr	743	855	*920	....	....	....	....	....	507	519	535	*548
$\frac{1}{2}$ N. S. Corr	442	502	583	680	....	....	....	....	450	452	458	*462
$\frac{1}{2}$ O. S. Corr	555	625	750	851	....	....	....	....	*486	....	....	....

* Maximum loads. † Maximum load was 425. ‡ Maximum load was 249.

TABLE VIII.—MAXIMUM LOADS ON BARS IN POUNDS PER SQUARE INCH OF EMBEDDED SURFACE WHEN SLIP DID NOT EXCEED THAT NOTED.

Specimens kept in water. (Age, 35 days.)

Size and kind of bar. Inches.	12-INCH EMBEDMENT.—DRY.				16-INCH EMBEDMENT.—DRY.				24-INCH EMBEDMENT.—DRY.			
	Slip in inches.				Slip in inches.				Slip in inches.			
	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{50}$	$\frac{1}{25}$
$\frac{11}{16}$ Round.........	317	363	*382	....	....	....	....	....	252	254	*256	....
$\frac{5}{8}$ Square..........	352	*436	....	....	....	....	....	....	253	257	*258	....
$\frac{3}{4}$ O. S. Corr.......	674	*753	....	....	....	....	....	....	495	*497	....	....
$\frac{5}{8}$ N. S. Corr.......	668	*749	....	....	....	....	....	....	*547	....	....	....
$\frac{1}{2}$ N. S. Corr.......	500	562	646	712	....	....	....	....	427	436	442	444
$\frac{1}{2}$ O. S. Corr.......	639	709	754	764	....	....	....	....	*450	....	....	....

* Maximum loads.

The results for the corrugated bars in this last series of tests are much the same as in the tests made last September, and, as would be expected, these bars developed a very great bond value, because of the abrupt angles of the corrugations.

CONCLUSIONS.

In view of the wide range in the value of the strength of bond between plain bars and concrete as reported by different observers, which range is from 83 pounds to 854 pounds per square inch of embedded surface, depending upon the smoothness of the bars, character of the concrete, and length of embedment, it seems impossible to formulate any rule for determining the value of bond or adhesion of plain bars in concrete.

It is also evident that while twisting of square steel bars does increase the strength of bond, this increase depends upon the degree of twisting the bars receive. In commercially twisted bars there is a great variation in the amount of twisting done and it is not unusual to see twisted bars of the same size delivered on work, some of which are twisted two to four times as much as others.

With reference to special shaped bars, such as corrugated and Diamond bars. Since these bars are delivered as they come from the rolls they are of necessity quite uniform as to surface. There would seem to be a marked advantage in having the corrugations or ribs on these bars placed at right angles to the direction of the stresses as in the corrugated bars, rather than at an oblique angle as in the Diamond bar. It is evident that either type of bar can be depended upon to develop the elastic limit of the steel without appreciable slip when placed in good concrete with a moderate length of embedment.

For corrugated bars or bars having equal bond value, an embedment equal in length to 30 times the diameter or length of side of bar, will, in good concrete, develop the elastic limit of the steel. If the concrete is to be under water or constantly wet, then for corrugated bars the embedment should preferably be forty times the diameter or length of side of the bar.

The importance of using bars with a mechanical bond in reinforced concrete is even greater for work that is to be under water or constantly wet, than where the structure is exposed to air on all sides. So far we have few data regarding the effect of repeated stresses, reversal of stresses, and shocks upon the bond between concrete and steel in reinforced concrete structures, but such information as we have indicates that there is a progressive breaking of the adhesion between steel bars and concrete under these conditions, and that, therefore, a mechanical bond between the steel and concrete is of great importance as a means of insuring against progressive failures in reinforced concrete.

DISCUSSION.

Mr. Brown. Mr. John G. Brown.—I should like to ask the author whether he makes it a point to select different bars of the same area of surface exposed to the concrete.

I should also like to inquire as to the elastic limit of the plain square and the plain round bar.

Again, my understanding is that when concrete is exposed to water it swells very much like wood. If that is the case, why, then, is this bond, or mechanical grip, less in the concrete immersed in water than for concrete in air? We are told that one of the best cements made for exposure in sea-water or in any water is made from a combination of iron and lime. It seems to me that we should get as good a bond in water as in air, if not better.

Mr. Condron. Mr. T. L. Condron.—In answer to the question as to the sizes of the bars referred to, I would say that a full description of the bars is given in the paper. In one set of tests the bars were all of practically the same size, and in another set of tests different sizes were used, but in all cases the results have been reduced to pounds per square inch of average area.

It seems appropriate at this time to make some comment as regards the specifications for bars to be used for reinforcing concrete. The specification for such bars should not be the same as for structural material. As you are aware, the best practice in making specifications for structural steel is to call for a steel of relatively low elastic limit and great ductility. In specifying such steel, the elastic limit being relatively low, there is a corresponding sacrifice in the elastic strength of our steel structures, and the only reason for making such a specification is to get a material which will withstand the punishment which structural material receives in fabricating a steel structure.

Any one who has worked in the mills, and especially in the shops, is familiar with the severe treatment steel receives in punching, shearing and drifting. It is entirely out of the question to use steel of high elastic limit and subject it to this kind of work in the shops, because these operations would start cracks in the steel which would lead to failure in the structure, and it is to secure a steel which will receive the minimum amount of injury from punching, etc., that low carbon steel is specified. **Mr. Condron.**

On the other hand, such steel as is specified for structural purposes would be entirely unsatisfactory for rails. For many years Bessemer steel, having an elastic limit from fifty to sixty thousand pounds, has been used for railroad rails, and certainly no steel has to withstand more severe stresses than the rails in track under heavy and rapidly moving engines and cars. It, therefore, seems to me that steel bars on which there is not any punching or shearing, except the cutting off of the ends, made of this same grade of steel, is a perfectly safe and suitable material to use for reinforcing concrete, and because of its higher elastic limit it is a better material for the purpose than ordinary structural steel.

We are all well aware that the ultimate strength of reinforced concrete is reached when the reinforcing steel is stressed but little beyond its elastic limit. We also have reason to believe that it is important that the factor of safety should be as great for the bond between concrete and steel as for the elastic strength of the reinforcing material, and therefore the ideal reinforcing material will be one having an elastic limit of not less than 50,000 pounds per square inch, and of such form that the full elastic limit can be developed without any danger of the bars slipping in the concrete.

Mr. Quimby. Mr. H. H. Quimby.—Mr. Condron's argument that old rails are good rails, goes only part way. The old rails are certainly sometimes rejected rails, and rails that have broken are not good rails.

I feel rather challenged by Mr. Condron's question as to why we should prescribe soft steel—the ordinary grade of medium steel—for reinforcing rods. The reason is that the modulus of elasticity of high carbon steel is no greater than the modulus of elasticity of soft steel, in fact, may be a little less, and the high carbon steel, therefore, will stretch just as much at service loads as our soft steel. If we permit twisted rods to be used in our work, we must insist upon its being the lower grade of steel, because the high carbon steel cannot be twisted cold. The only reason for twisting the old rail steel rods hot is that they cannot be twisted cold. It costs more to twist them hot, and you do not get as uniform a twist.

Mr. Brown. MR. BROWN.—The author has only answered one of my questions and not those I particularly desired.

In the first place, I asked him as to the effect of water on the bond of steel imbedded in concrete.

Again, the author has used a soft steel and compared that with the high-carbon steel; that is, the Johnson bar. The limit of bond seems to be the elastic limit, which is usually from 28,000 to 36,000 pounds per square inch.

Mr. Talbot. MR. A. N. TALBOT.—So far as one question asked, the reason for the difference between the bond resistance in concrete set in air and that set in water, is concerned, it may be that this may throw some light upon it. In general, we may say that concrete which is set in air shrinks or contracts in setting considerably; while that set in water contracts relatively little. A large part of the bond resistance with plain rods is due to the grip against the rod itself, together with the difference in section throughout the length of the bar which comes from rolling. We may then naturally expect that concrete which has contracted around a piece will give higher resistance in the bond test than concrete which has contracted less.

The effect of the difference in section is perhaps a larger element in this than the difference in smoothness of surface of the test piece. In tests made with tool-steel bars—round only, smooth, but very regular in cross-section—the amount of the bond resistance developed was perhaps one-third as much as the bond resistance of ordinary mild steel rolled rods; but the difference in diameter in adjoining sections along the length of the rod was also markedly different, and this variation in section makes the plain mild steel rod partake of the nature of a deformed bar.

At times objection has been made to the usual method of making the bond test, from the fact that compression is brought upon the concrete—the head of the machine being placed against the concrete block. This year we made some tests in which the concrete itself was held in tension, two bars being placed so that they came in contact with each other at the middle of the length of the concrete block, and the stress from these bars was carried as tension through the concrete. We found that the results were practically the same as those obtained by the other method.

Mr. Thacher. MR. EDWIN THACHER (by letter).—During the past few years a large number of tests have been made by different experimenters on the bond between concrete and steel, in which plain bars and various kinds of deformed bars have been used, but unfortunately the great majority of such tests have no value and are not comparable, for the reason that the limit of elasticity of the steel has been greatly exceeded. In many cases the elastic limit and ultimate strength of the steel is not given, and this has quite as much to do with the result as the form of bar. Thacher bars have usually been rolled from soft or medium steel, and in many, if not the majority, of tests on this bar the bar has been broken without giving any means of estimating the bond. To determine the real bond between concrete and any style of bars the pulling out resistance should not much, if any, exceed the elastic limit of the bar. With plain bars, if the elastic limit is exceeded, the bars are reduced in section, where they enter the concrete, relieving the bond, and as the stress per square inch is increased this relief extends deeper and deeper into the concrete and the bond resistance per square inch of surface is diminished. With deformed bars, if the elastic limit is exceeded, the increased and unequal elongation will cause the corrugations or projections on the bars to split or crack the concrete, so that the result in this case also is incorrect. Some few tests have been made in which the embedment was not so great as to stress the rods beyond their elastic limit, and I will quote such as I have been able to find most readily, and which appear to be most reliable. **Mr. Thacher.**

Tests made at Columbia University for the Rapid Transit Commission in 1903:

Bond per square inch of surfaces embedded. Concrete 1 month old.

	Lbs.
Plain bars rusted	437
“ “ clean	294
“ “ in water	170
“ “ coated with red lead	63
“ “ “ “ oil	33
“ “ “ “ graphite	10
Thacher bars (average of two tests)	744
Ransome bars (“ “ “)	521

Tests made by Professor Arthur N. Talbot, University of Illinois Bulletin No. 1, September, 1904, Table VII, bond in pounds per square inch of net surface.

	Lbs.
Johnson bars (within elastic limit) 7 tests, mean	420
Plain bars, round and square	284

Mr. Thacher. Bond tests giving stress per square inch of area are not comparable, unless the areas are equal, and the stresses are all within the elastic limit.

As the perimeter varies as the diameter, and the area as the square of the diameter, it is evident that in tests for bond on bars of different areas the perimeter only should be considered.

Tests made at Lewis Institute, Chicago, by Professor C. E. DePuy, for T. L. Condron, Expanded Metal and Corrugated Bar Company, in 1906. Concrete 25 and 31 days old. See Journal Western Society of Engineers, February, 1907. Tests were made with 8, 12, 16, 20, and 24 inches embedment, and comparisons made for slips not exceeding $\frac{1}{100}$, $\frac{1}{32}$, $\frac{1}{16}$ and $\frac{3}{32}$, giving 20 sets of results altogether. But with two exceptions these results have no value for purposes of comparison as the elastic limit of the Thacher bars was much exceeded.

The comparable results are as follows:

Kind of Bar.	Size of Bar. Inches.	Area of Bar. Sq. In.	Perimeter of Bar. Inches.	Embedment 8 Inches.			
				Stress per Square Inch of Embedded Surface.			
				Slip Not Over $\frac{1}{100}$ Inch.	Slip Not Over $\frac{1}{32}$ Inch.	Average Stress.	Comparative Results.
Round	$\frac{11}{16}$	.378	2.17	198	198	198	100
Square	$\frac{5}{8}$	.390	2.50	232	271	251	127
Twisted, B ...	$\frac{5}{8}$	.395	2.51	250	283	266	134
" R ...	$\frac{5}{8}$	.395	2.51	382	500	441	222
Thacher	$\frac{5}{8}$	.385	*2.20	*555	*738	*646	*326
Corrugated, N.	$\frac{5}{8}$	.368	2.43	452	626	539	272
" O.	$\frac{3}{4}$	.424	2.60	594	784	689	348

The average results given in Mr. Condron's paper for 8, 12, 16, 20 and 24 inch embedment are misleading and the conclusions drawn therefrom by Professor De Puy are from incorrect premises.

Some tests were made by Professor C. W. Spofford, Massachusetts Institute of Technology, in 1903. The results are not very satisfactory or conclusive. The embedment was too great, the stress on the bars in most cases being much above their elastic limit.

Tests on $1\frac{1}{8}$ and $1\frac{1}{4}$ inch bars with 27, 37 and 50 inch embed-

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*Estimated from area of bar and embedment.

Mr. Thacher. ment give the following average stresses per square inch of embedded surface:

Ransome bars	583	pounds.	The stress on some of these bars probably exceeded the elastic limit.
Thacher bars	979	"	
Johnson bars	957	"	

Some tests were made at Lewis Institute, Chicago, by Professor C. E. DePuy, for T. L. Condron, in June, 1907. Unfortunately the same mistake has been made in all of these tests that was made in the great majority of the tests above referred to, made in 1906. The least embedment reported in these tests is 12 inches which, for a slip not exceeding $\frac{1}{200}$ inch, gave a stress on the Diamond bar of 44,100 pounds per square inch, which probably much exceeded its elastic limit.

Diamond bars have been rolled from soft, medium and medium-hard open-hearth steel, the elastic limit probably ranging from 30,000 pounds to 45,000 pounds per square inch. The first rolls used also gave less height of ribs than the present rolls, so without knowing the kind of rolls and grade of steel used for the Diamond bars, it is impossible to draw any satisfactory conclusion from the result of these tests.

Professor Talbot recognizes the unreliability of tests for bond due to stretch (see Bulletin No. 8, University of Illinois, Vol. 4, September, 1906), but with this exception experimenters do not appear to have considered it.

Some tests for bond on plain and deformed bars were made by Professor Edgar Marburg, University of Pennsylvania, in 1904. (See Proceedings, Vol. IV.) The bars used had a nominal size of ½ inch and were embedded 12 inches in the concrete. Eight of the nine specimens of deformed bars tested were stressed much beyond their elastic limit, and two of the three Thacher bars tested were broken, so the results do not admit of comparison. The plain bars pulled out at an average stress of 24,100 pounds per square inch, or at about 0.6 the elastic limit.

Some tests were made by the Philadelphia Rapid Transit Commission on Thacher, Ransome and Johnson bars. The bars were embedded too deeply in the concrete. All of the Thacher bars broke without pulling out. The other bars pulled out under stresses much exceeding their elastic limits, so the results are not comparable.

Mr. Thacher.

Some tests were made at Lewis Institute Chicago, by Professor C. E. DePuy, for the Concrete-Steel Engineering Company of New York, in March, 1907. Professor De Puy reports that the cement was of poor quality, and that the results are of value only for comparative purposes. Embedment, 8 inches. The results are as follows:

For tests on each bar, the maximum stress not exceeding 18,800 pounds per square inch.

	Area. Sq. In.	Average Stress. Lbs. per Sq. In.	Average Slip, in Millimeters.
⅝-in. diamond bars	.41	12,250	.280
¾-in. " "	.56	12,900	.237
⅝-in. new corrugated bar	.38	12,200	.275

As the rate of slip is not in proportion to stress it is difficult to make any satisfactory comparisons with tests of this nature. An attempt has been made to obtain the average slip for average stresses, the latter being as nearly equal as possible.

Some further tests were made by Professor De Puy, for the Concrete-Steel Engineering Company, on September 3, 1907, but the embedment was too great and the results have no value.

My conclusion is that nearly all the tests for bond between concrete and the various styles of deformed bars, thus far made by different experimenters have very little value, either for determining the true resistance within the elastic limit of any particular bar or for the purpose of comparing one bar with another.

Mr. Condron.

MR. CONDRON (by letter).—The author in presenting his paper describing the tests of bond between steel and concrete made by Professor DePuy, has done little more than to put the results of these tests in a convenient form for study, and he believes that if the diagrams shown in Figs. 3, 4, 6 and 7 are examined they will clearly show the resistance to slipping which different forms of bars offer when embedded in concrete under identical conditions. They also show graphically the fact that short embedments in average rock concrete do not develop the full bond strength of deformed bars, and further that the elastic limit of bars is a factor of the bond strength.

Mr. Thacher in his discussion calls attention to the elastic

Mr. Condron.

limit of bars as a factor in bond strength, which, of course, is recognized by every engineer. The author limited his paper to the bond strength of the bars used in these tests, and while he might have expanded the paper by going into other properties he did not consider it necessary. If the bars are so formed as to have practically the same bond strength after the elastic limit is passed as before, the elastic limit will not be a marked factor in the bond strength of such bars. Undoubtedly in the plain bars the strength of bond will be seriously impaired, if not entirely destroyed, at or before the elastic limit is reached. In reinforced concrete construction the aim is to develop the full elastic limit of the reinforcing, and up to this point the strength of bond should be sufficient to insure the bars against slipping.

In the author's paper nothing has been omitted which he thought would be of value in this connection, nor has he drawn any conclusions from only a portion of the data, but he has presented all of the results of the tests made, and such few conclusions as he has drawn are based on all of the results.

Mr. Thacher has referred to tests made by others, and it may be of interest to comment a little further on these tests.

In the test reported by Professor A. N. Talbot, Bulletin No. 1, University of Illinois, apparently there has been an error made in computing the area of the Johnson bars. It has been assumed there that the ½-in. Johnson (old style) bar, having an area of 0.20 square inch, has a perimeter of 2 inches. The bar referred to is, therefore, assumed as having a perimeter as great as that of a bar weighing 25 per cent. more, or having an area of 0.25 of a square inch. Likewise the so-called ¾-in. Johnson (old style) bar having an area of 0.365 square inch is assumed to have a perimeter of 3 inches, equal to the perimeter of a bar 52 per cent. heavier than the bar tested. The average perimeter of the ½-in. Johnson (old style) bar should be given as 1.788 instead of 2, and the average perimeter of the ¾-in. Johnson (old style) bar should be given as 2.416 instead of 3. Therefore, while the results given by Professor Talbot based on the areas of cross section of the bars is correct, those results based on the areas of embedded surface of bars are in error, and in the case of the ½-in. bars are about 12 per cent. too small, and in the case of the ¾-in. bars about 30 per cent. too small.

Mr. Condron. In Bulletin No. 1, Professor Talbot gives the results for Johnson bars as ranging from 298 to 639 pounds, and had the correct areas of embedment been used these figures would become 388 and 750 pounds per square inch of embedded surface for the Johnson bars. He gives the results for the plain bars, in which, of course, there is no error in the determination of the area of embedment as ranging from 174 to 360 pounds per square inch of embedded surface. In these tests of Professor Talbot's the embedment was 12 inches which is not sufficient length of average rock concrete in which to develop the bond strength of properly deformed bars. Professor Talbot states: "It will be seen that the Johnson bars split the concrete. No slipping could be detected before the maximum load was reached."

It is difficult to determine what the "area of surface" is of a deformed bar, but the author has used the following method of arriving at the average areas of section and areas of surface of bars:

$$\text{Average area of section} = \text{weight of bar 1 ft. long} \div 3.4$$

$$\text{Average perimeter of round bar} = \sqrt{4 \times 3.1416 \times \text{area}} = \sqrt{3.7 \times \text{weight of bar 1 ft. long}}.$$

$$\text{Average perimeter of square bar} = 4\sqrt{\text{area}} = \sqrt{4.7 \times \text{weight of bar 1 ft. long}}.$$

If Mr. Thacher had taken the mean of Professor Talbot's tests without the arbitrary, "within the elastic limit," he would have given the mean as 485 for Johnson bars instead of 420, and had the proper surface areas been considered the figure would be 607 pounds per square inch of embedded surface for the Johnson bars, even when the tests resulted in the splitting of the concrete before the bars began to slip. It is also interesting in this connection to note that in more than half of these tests the Bulletin states that the bars before testing were "struck six quarter swing blows with a 10-pound sledge." Apparently these results were pretty good under the circumstances, and compare very favorably with the tests made by Professor DePuy on a 12-inch embedment shown in Fig. 4.

Passing now to Mr. Thacher's table of the tests by Professor DePuy, he has added the results for the Thacher bars. The original report states: "As there was no way of readily determining

Mr. Condron

the surface areas of the Thacher bars, these are not included in Fig. 4 and Table III." The results for these bars, in pounds per square inch of cross section, are given in Fig. 3 and Table II, however. Mr. Thacher gives the average perimeter of his bar, having an area of 0.385, as 2.20. This would be correct if the bar were a round bar like his later design, the so-called "Diamond bar." But as the Thacher bar is as much an oval as a round bar, the question naturally arises, what is the average perimeter? and it is evident the average perimeter is greater than the minimum possible perimeter. This average perimeter if actually determined would be at least 10 per cent. greater than 2.20 and might be as much as 20 per cent. greater. In any case the resulting stress per square inch of embedded surface would be at least 10 per cent. less than Mr. Thacher gives.

Mr. Thacher refers to Professor Spofford's tests in 1903 and states that the embedments were too great, but he only quotes the longest embedments; namely 27, 37 and 50 inches. It may, therefore, not be out of place to state that in these tests, as reported in *Beton und Eisen* and reprinted in the *Railroad Gazette* of September 18, 1903, the lengths of embedment were 12, 16, 20, 24, 26, 27, 31, 36, 37 and 50 inches, but confining ourselves to the 12- and 16-inch embedments, which are not "too great," the results as published in the *Railroad Gazette* are given on page 474.

These results are of especial interest because Professor Spofford calls attention to the fact that in certain tests the rods began to slip at low loads, after which initial slipping the loads were increased very greatly, and in one instance he records the rod as slipping 5 inches, presumably before the maximum load was reached. It was this fact that led the author to have tests made by Professor DePuy, in which special means were taken to observe the actual movement of the bars as the loads were applied.

With reference to Professor Marburg's tests, Mr. Thacher says two of the three Thacher bars tested broke. It is evident that in such concrete as Professor Marburg used, 12 inches embedment was sufficient to develop the ultimate tensile strength of the Thacher bars used, namely about 52,000 pounds per square inch, and did develop as high as 76,000 pounds per square inch tension in the Johnson bars.

Mr. Condron.

RESULTS OF TESTS ON THE UNION BETWEEN CONCRETE AND STEEL.

By Prof. C. W. SPOFFORD, Massachusetts Institute of Technology.

No. of test.	Type of rod.	Size, inches.	Size of concrete block, inches.	Length of rod embedded in concrete, inches.	Breaking load, pounds.	Minimum area of cross-section of rod, sq. in.	Shearing stress in pounds per sq. in. of net section.	Stress on rod in pounds per sq. in. of net section.	Remarks.
1	Ransome	½	6x6	12	12,100	0.25	504	48,400	Concrete split longitudinally.
4	Ransome	½	8x8	12	8,300	0.25	346	33,200	Rod slipped at 8,000, dropped to 6,000, rose again to 8,300, where concrete split. Rod pulled through 3 in.
13	Thacher	½	6x6	12	4,850	0.18	270	26,900	Rod slipped, concrete split.
22	Johnson	½	6x6	12	12,200	0.14	678	87,200	Concrete split.
2	Ransome	½	6x6	16	8,100	0.25	253	32,400	Concrete split longitudinally.
5	Ransome	½	8x8	16	14,000	0.25	438	56,000	Rod slipped at 12,000, dropped to 8,000, rose again to 14,000, where concrete split. Rod pulled through 5 in.
14	Thacher	½	6x6	16	8,200	0.18	340	45,500	Rod slipped at 8,100, concrete split.
23	Johnson	½	6x6	16	13,120	0.14	545	93,700	Concrete split.

It seems to the author that it is more profitable in bond tests to study the stresses in pounds per square inch of section of the bars instead of stresses per square inch of embedded surface. The bond resistance is not proportional to the area of embedded surface, although the area of surface is a function.

Mr. Thacher says: "The average results given in Mr. Condron's paper are misleading, and the conclusions drawn therefrom by Professor DePuy are from incorrect premises." Professor DePuy cannot be charged with drawing any conclusions from the author's paper, but the author has drawn some conclusions from Professor DePuy's report, without comments, of the results of certain tests. As Mr. Thacher fails to state in what particulars the results given are misleading, the author is unable to defend himself. The results speak for themselves. Nothing has been garbled or distorted and no effort was made to do more than present a record of interesting and instructive tests for the information of those who are seriously looking for such data.

NOTES ON BRICK PIER TESTS.

BY JAMES E. HOWARD.

An ultimate crushing strength of 5,608 pounds per square inch represents the maximum resistance which has been displayed by a brick pier in the Watertown Arsenal tests. There are a number of instances in which the crushing strength has exceed 4,000 pounds per square inch, and it is a comparatively easy matter to build piers which shall display at least 3,000 pounds per square inch ultimate strength. It is believed that the maximum limit for piers has not been reached, and that even higher results may be obtained by the use of some of the stronger brick, examples of which are found among the tests of individual samples, but which have not yet been tested in pier construction.

The strength of individual brick not infrequently ranges from 15,000 to 25,000 pounds per square inch, while one of phenomenal resistance displayed a crushing strength of 38,446 pounds per square inch. The possibilities of strength in clay products are shown in the test last mentioned, that of a vitrified shale brick, the honor of making which belongs to the St. Louis Vitrified and Fire Brick Company.

The results of tests of fifteen piers are presented herewith, compiled for convenience of reference from several of the annual reports of "Tests of Metals." These are selected results on piers which have shown an ultimate strength of 3,000 pounds per square inch or more. These strong piers were made of hard-burnt brick, laid in neat cement or cement mortar. Their dimensions were about 8 feet high by 12 inches square. The Arsenal tests also include results on other grades of brick laid in different kinds of mortar. It has been intended to show not only the degree of strength and rigidity attainable in brick work, but also to illustrate the strength and behavior of the more ordinary examples where considerations of strength do not control. There are therefore results on piers made of light-hard brick laid in lime mortar, representing the less strong and less rigid kinds of work. Strength

RESULTS OF TESTS ON BRICK PIERS.

No of test.	Description of bricks.	Pier laid in	Age.		Weight per cu. ft.	Net sectional area.	Compressive strength.		Moduli of elasticity between loads, per square inch of			Permanent set on gauged length of 50 inches after loads in pounds per square inch of		
							Total.	Per sq. in.	100 and 600.	600 and 1,000.	1,000 and 2,000.	600.	1,000.	2,000.
			Mos.	Days.	Lbs.	Sq. in.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Inch.	Inch.	Inch.
1694	Wire cut bricks, Dover, N. H.	1 cement, 5 sand	8	20	136.0	121.15	363,450	3,000	2,809,000	2,469,000	2,262,000	.0005	.0011	.0035
1695	Dry pressed bricks, Charlestown, Mass	"	8	21	136.9	120.79	415,100	3,437	2,717,000	2,439,000	2,358,000	.0007	.0014	.0040
1699	Dry pressed bricks, Charlestown, Mass...........	"	8	18	137.3	110.68	384,000	3,299	2,632,000	2,381,000	2,165,000	.0026	.0038	.0079
1760	"Johnsonburg, Pa."......	Neat cement ...	0	5	143.7	118.77	501.000	4.218	4,032,000	3,704,000	2,381,000	.0020	.0030	.0086
1761	"	" ...	0	7	144.8	119.65	671,000	5,608	4,237,000	4,444,000	3,817,000	.0013	.0025	.0045
1763	"Shawmut, Pa.".........	" ...	0	2	141.5	112.78	421,000	3,733	3,425,000	3,030,000	2,890,000	.0030	.0074	.0254
1764	"	" ...	0	7	145.6	112.98	510,000	4,514	4,386,000	3,704,000	3,356,000	.0011	.0020	.0048
1767	"Johnsonburg, Pa."......	" ...	1	8	145.2	118.21	506,000	4,281	3,906,000	3,774,000	3,571,000	.0011	.0018	.0033
1768	"	" ...	1	8	143.6	119.52	598,000	5,003	5,208,000	5,128,000	4,202,000	.0008	.0015	.0024
1780	"Shawmut, Pa."	" ...	4	7	143.1	110.79	453,000	4,089	4,717,000	4,082,000	3,846,000	.0011	.0016	.0035
1506	Hard, West Cambridge, Mass.	" ...	1	0	135.5	132.60	623,600	4,700	2,403,000	2,326,000	2,336,000	.0014	.0027	.0058
1636	Face, wire cut, Dover, N. H.	" ...	5	23	133.6	141.49	569,000	4,021	2,381,000	2,273,000	2,165,000	.0015	.0025	.0056
1671	"	1 cement, 2 sand	2	12	134.4	143.64	542,000	3,775	2,809,000	2,778,000	2,577,000	.0012	.0018	.0039
1644	Hard, Rochester, N. H. ...	Neat cement...	5	24	133.2	142.80	650,000	4,552	1,709,000	1,818,000	1,908,000	.0022	.0031	.0058
1645	"	1 cement, 3 sand	5	22	130.3	142.32	487,000	3,422	2,119,000	1,923,000	1,845,000	.0023	.0038	.0100

and rigidity are controllable features and may be regulated, within limits, by selection of the brick and choice of mortar.

During the early stages of loading, piers which are made of hard-burnt brick laid in cement mortar show moduli of elasticity in the vicinity of 3 million to 4 million pounds per square inch. As the loads advance the value of the modulus commonly drops somewhat, an effect attributed to the action of the mortar. Permanent sets are of small magnitude in piers of this class. If lime mortar is used large sets are developed and lower moduli of elasticity prevail, the yielding of the mortar also exerting an unfavorable influence on the ultimate strength of the pier. Regularity in shape of the individual brick promotes strength in the pier. The modulus of elasticity of strong mortar or neat cement is less than that of hard-burnt brick, hence it follows that the best cushioning effect at the joint is reached when the mortar is of even thickness.

Piers commonly rupture by the development of longitudinal lines of fracture, the brick being broken into halves across the middle of their lengths. In some cases the ultimate strength is reached by reason of the direct crushing of individual brick, but the usual manner of rupture is the development of transverse lines of fracture tending to convert the pier into a clustered column of half-brick.

Means which defer the development of longitudinal cracks might be expected to promote strength and it is thought that some assistance may be afforded by modifying the manner of laying the brick. The transverse strength of a brick on edge should be greater than on the flat, and apparently some gain in strength in the pier has resulted from laying the brick on edge instead of on the flat. Also breaking joints at less frequent intervals, laying six or seven courses and then breaking end joints, has seemed to promote strength, over the usual manner of laying. The use of strong bond stones, in their cross section dimensions as large as the pier, should likewise aid in giving strength.

It is an element of weakness, however, to carry up a smaller pier on the top of a larger one without the interposition of a strong stone or plate, to relieve the larger pier of transverse strains at its junction with the smaller one. A remark of this kind would apply to foundation courses in regard to corbels, which should have steps of limited extent.

The strength and rigidity of a pier increases with age, due to the hardening of the mortar. By the use of strong brick, however, a high ultimate strength may be acquired within a comparatively short interval of time. It so happened that the pier first mentioned, which displayed the highest strength yet observed, was only 7 days old when tested. Another pier was built in the forenoon and tested in the afternoon of the same day. This pier, when four hours old, displayed a crushing strength of 2,106 lbs. per square inch, or over 144 tons per square foot. During construction it would not be practical to load the pier so heavily by chance at this age, and therefore if properly designed for carrying its load under final conditions would be regarded as safe beyond doubt.

PRIMING COATS FOR METAL SURFACES—LINSEED OIL vs. PAINT.

By F. P. Cheesman.

Previous to 1885 it was almost a universal custom to use boiled linseed oil as a shop or priming coat for metal. This was largely due to the fact that but little attention was given in those days to the subject of corrosion, while to-day we have almost gone to the other extreme and corrosion has become a favorite topic at our meetings. The theories presented differ so much that the layman is apt to grow confused and throw up his hands in despair; and yet the agitation has resulted in great improvement and progress in preventing corrosion, notwithstanding the destructive forces that we have to contend with increase in number yearly, and the metal that we have to protect in many cases is no longer passive, but also frequently produces a destructive attack from the rear upon the protective coatings applied to the surface. At the present time very few bridge engineers specify the use of boiled oil, and yet there are enough still doing so to make it worth the effort to call their attention to the fact that they are making a mistake and inviting corrosion by so specifying.

I will not attempt to go into the chemistry of linseed oil, the fact being that we know less about linseed oil than probably any other oil used in the manufacturing trade, and this is due largely to the fact that we cannot seem to get a recognized standard for linseed oil, owing to the great changes which take place in the article itself, the yield of oil from year to year varies from 22 to 34 per cent. from North American seeds, while it has been known to go as high as 40 per cent. in foreign seeds, while the percentage of water ranges from 6 to 10½ per cent.

For the paint trade the quality of the oil is measured by its power of absorbing oxygen, and, rated by that standard, Baltic seed is No. 1, Bombay, Calcutta and Black Sea seed No. 2, North American seeds No. 3, although there is quite a difference in the values of North American seeds, Dakota seed making better oil than Missouri seed, and seed from new soil better oil than from old soil on which fertilizers have been used. Argentine seed is No. 4, or poorest. The quality of the seed does not seem to depend upon climatic conditions so much as upon the quality of the soil.

At a meeting in 1906 of the New York section of the Society of Chemical Industry, Dr. Sabin, in an article on "The Oxidation of Linseed Oil," showed that after the same oil had been placed in six glass flasks connected together with tubing and allowed to stand in a well lighted room, there was such a difference in the weight after drying that one had gained two and one-half times as much as the other, the figures being 10.1 and 25.5 per cent. Dr. P. C. McIlhiney, at the same meeting, said with regard to the atmospheric oxidation of linseed oil he had himself found that the same sample of linseed oil would at different times and under conditions that were apparently the same, absorb very different percentages of oxygen, or at least that the increase of weight on drying was very different. I mention the above to show why it is possible to have conflicting results when the paint maker has made no change in his vehicle. Linseed oil is to-day the best paint vehicle we know of, but it contains some of the still unknown mysteries of nature, and it occasionally gives us a knockout blow.

While a few still contend that linseed oil when dry is not porous, the majority believe (and especially as applied to boiled linseed oil) that it is hygroscopic in its nature, the proof of the pudding cannot in this case be found in the eating, but it can be found in the following field tests.

Several very interesting facts were stated by practical men at the third annual convention of the Maintenance of Way Master Painters' Association of the United States and Canada, held in New York, November 13 and 14, 1906, and are printed in their proceedings, and I will mention the following:

Mr. Edward Hurst Brown, in his paper on "Conditions That Must Be Met in the Ideal Paint for Railway Bridges," stated as follows:

> The most insidious enemy of the iron bridge is rust, and the primary object of painting it is to protect it from those elements which cause destruction by rust. Rust is caused by the combination of the metal with oxygen to form the hydrated oxide of iron. This oxygen may be obtained from the air, from water or from some other substance which acts as a carrier of oxygen or an oxidizing agent—always, however, in the

presence of moisture. Now, one of the primary things to be considered in choosing a paint for ironwork is that it shall not contain in its pigment or vehicle any substance which is chemically active in such a way as to convey oxgyen to the iron. For if such a chemically active agent be introduced into the paint, sooner or later it will promote rather than prevent rust. Of course, so long as the oil, in an oil paint, remains intact it envelops the particles of pigment and keeps them away from the iron, but in time the oil, which has hardened by absorbing oxygen from the air, begins to disintegrate by the action of water coming from rain, hail, snow or fog. Moreover, even the freshly applied oil is not absolutely impenetrable to moisture, as has been shown by numerous experiments, and however completely the particles of the chemically active pigment may be covered by an oil film, they will necessarily come in contact with moisture—will decompose the water and absorb its oxygen, and convey it, together with the hydrogen, to the surface of the iron to cause rust. For this reason the ideal paint for a steel or iron bridge should not contain a chemically active pigment, nor any strongly oxidizing agent in the way of driers.

We have also seen that linseed oil is permeable to moisture and to the gases and steam from locomotives. This was first clearly demonstrated, we believe, by Dr. C. B. Dudley, Chemist Pennsylvania Railroad, and to this fact may be ascribed the corrosion of the metal under an apparently intact coating of paint. It is true that in the mixture of oil with pigment in a very finely divided form the tendency is for the pigment particles to more or less fill up the interstices in the oil film and render it less porous. How completely this is done depends more or less upon the shape of the minute particles of pigment, and as Mr. Robert Job, formerly Chemist, Philadelphia and Reading Railway, demonstrated in a paper read before the Franklin Institute, it depends even more largely upon the fineness of grinding of the pigment particles. The finer the pigment is ground, the more perfect will be its protective power. This was shown very clearly by examination of the paint film under the microscope as well as by actual service tests.

J. B. Houser, M. C. P., C. V. R. R., and President of the Master Car and Locomotive Painters' Association, stated the following experiences:

We have a bridge crossing the Potomac River; I do not recall just when that was painted—perhaps in 1892. That came to us with a coating of boiled oil, and we have had quite a good deal of trouble with it.

I do not like to see a coating of boiled oil on a bridge—I would rather have it a little rusty than with this shop coating of boiled oil. I believe we can take care of rust before the bridge is painted better than we can after it has this shop coating, it seems to hold the blue scale for a little while, but will finally give way. We had the same trouble on a bridge at Martinsburg, although we tried to clean it the best we could. I think if the shop coat of boiled oil had been left off we would have had no trouble. I do not know what experience you have had, but this has been mine—on new work, of course. Old work we have to take care of as everybody else does; we scrape it where necessary, and as a rule give two coats of paint. But I would like to know if the experience of others with boiled oil has been the same as mine.

.H. J. Barkley, of the Illinois Central Railroad:

We have had the same experience, Mr. Houser. We had fifty sets of plate girders come to us with a shop coating of boiled oil—I suppose it was given so as to not cover up the shop marks—and we had similar experience with them; a wire brush had no effect on the oil. They have been in use for five or six years, and are in a terrible shape. We could not get off the blue scale and rust when they were first painted.

Mr. J. H. Cummin, Superintendent of Bridges and Buildings, Long Island Railroad, said that he did not believe we could lay that to the manufacturers of steel work. The engineers specify how the steel is to come from the works; some specify a coat of boiled oil; some a coat of red lead. So you want to get back at the engineers, not the manufacturers.

The writer, in the course of his remarks, made the following statements:

Any practical master painter will allow that boiled linseed oil when used alone for the first coat on metal will not dry hard in weeks. It oxidizes on the surface, absorbing moisture and forming a skin, leaving the underneath portion soft and easily knocked off in shipping and later on will cause subsequent coats of paint to crack and peel. This is because the first coat of oil must dry some time, and in doing so will force the top coats to crack, and sooner or later come off.

Mr. Emil Gerber, in his report on the Illinois Central Railroad bridge at Cairo, Ill., shows that the approaches which received one shop coat of paint weathered better than the bridge which received one shop coat of oil. When the Cumberland Valley Railroad bridge was built in 1887 at Harrisburg, Pa., it was built jointly by the Edgemore and Union Bridge

Works, and one applied a shop coat of paint and the other a shop coat of oil. After erection it was found that the oiled part of it was rusting very badly. Two coats of our paint were soon applied on the entire structure, and the section that received one coat of paint at the shop stood much the better. Mr. R. I. Sloan, late Chief Engineer of the South Side Elevated Railroad, Chicago, Ill., specified oil for priming coat. He allowed the Lassig Bridge and Iron Works Company to paint the section that they built at their shops with one coat of oxide of iron paint, and the structure received two coats of our light colored paints. The section built by Lassig, covered with three coats of paint, weathered much the better.

We also quote from Mr. M. P. Wood's book on "Rustless Coatings":

> Many engineers advocate the use of boiled oil alone for the first or priming coat, applied either at the rolling mill to protect the metal during its transit from the mill to the construction shop, or at the shop when ready to ship for erection. The general reason assigned for this practice is that the boiled oil "soaks into the scale and dries and prevents further tendency toward corrosion".

This theory is absolutely without proof from any standpoint. How far any oil or liquid can soak into iron or steel, or the still harder mill scale that forms on these metals, these Solons do not state. The use of such oil coatings is, in general, to conceal some slopwork on the part of the inspector, or constructor, at an earlier stage of the work than would be possible later on. However consistent and beneficial the first coating of oil may be for a wood or masonry surface, it has no part or parcel on a metallic one, when applied for the correction of the mill scale evil. No number of these oil or even paint coatings will soak into and bond these scales together, or to the metal surface. There are hundreds of records of the painting of important railway structures, where the first coat of boiled oil method was used, and, in the great majority of instances, the utter and rapid failure of the coating, and the extra corrosion of the structure, could be directly assigned to this so-called method of protection.

The weather-resisting power of an oil coating is almost nil compared with a paint, as before referred to in Dr. Dudley's experiments. If the advocates of oil coatings are so sure of its benefits as against a paint, why not make all the coatings of oil alone, no matter what it covers, a wire or an anchor? It will soak as far into one as the other. A paint coating can be applied as quickly and easily to any surface as an oil coat; will dry as quickly and as hard, and is in every way a better resistant to atmospheric or mechanical injuries.

A foundation coat of oil is a direct cause of the blistering and peeling of the coatings spread over it. It is seldom dried enough before the other paints are spread over it to ensure a close adherence to the metal it covers. When the subsequent coats of paint are spread the solvents and oils in them soften to some extent the underlying coat of oil, and a moderate heat from the sun causes the whole coating to blister or peel. Too much oil in a paint coating, particularly if the surplus oil is in or near the foundation coat, whether on a wooden or metallic surface, will generally cause peeling regardless of the pigment used in the coatings.

In 1904 I examined with Mr. Byrnes, who was the Engineer in Charge, the Newtown Creek Bridge, New York City, a new structure then being erected, and on which had been applied a shop coat of boiled linseed oil, and we found the steel underneath very badly corroded, and he stated then that it would be the last time that he would ever allow the use of boiled linseed oil, if he had anything to say about it. A few months ago I had occasion to examine one of the new piers being erected in New York City with the engineer, and found the same trouble there—corrosion under a coating of boiled linseed oil—and he was convinced that to specify linseed oil for a priming coat led to poor results.

I might go on and cite many other cases, but I think that I have taken up enough time and produced enough evidence to show that linseed oil by itself is a bad thing. The question now arises, What pigment would you recommend using in connection with linseed oil for a priming coat? and to this I answer that the paint doctor must be advised upon several points before he can prescribe the proper pigment.

Will the metal be painted under cover and how much time will be allowed for drying? If it is a rush job, we want to use a pigment that will not retard the drying of the oil, as, for instance, carbon black is a very durable pigment, but it does not want to be used on a rush job. Is the material to be shipped a long distance, and what kind of exposure will it have before it is second coated?

Will the metal be properly cleaned before the shop coat is applied? All of these questions must be answered before we can state intelligently what is the best pigment to use, but where no information can be obtained, as a general rule, it is safe to use a selected high grade natural ore iron oxide paint, while for many locations a blue lead paint would be best, and in others a combination of red lead and graphite, or a carbon black paint. It is safe to say that more paint is spoiled in the application than in the manufacturing of it, and the inspector's chief efforts should be to see that it is well brushed on and the metal properly cleaned.

DELETERIOUS INGREDIENTS IN PAINTS.

By L. S. Hughes.

In considering what has been written on the subject of paint materials it is noticeable that little effort has been made to discover underlying principles, arguments being generally based on exposure tests, the popularity of some certain ingredient or on factory experience. This piling up of unsystematized and unrelated data will do very little to bring about an understanding of the subject. Every paint maker has his individual preferences as to paint ingredients and each one could easily arrange a catalogue declaring this pigment good and that one bad, but there would be little correspondence between the different lists. As the opinions of the men in any one factory are generally pretty much the same, I am inclined to think this wide variance of opinion is due, not to careless observation, but to differences in behavior of the same paint under different conditions of climate and exposure. Generalizations cannot be made from the records of one locality, and it is only by systematizing results from a large number of places that the essential characteristics of a pigment can be determined.

Inasmuch as a pigment liable to change upon exposure manifestly affords a chance for greater variation in final conditions than one which does not change, it is not surprising that the greater weight of evidence indicates that a paint made from chemically stable pigments behaves more consistently than one made with reactive substances. As to the relative wear of the two classes of pigments we find instructive information in the trend of iron protective coatings in which the tendency is more and more to seek chemically inert pigments. This subject of iron protection is most important in considering paint composition because the surface is almost ideal for a just comparison of different paints.

Another point which seems to have a distinct bearing upon the effect of stability is the superiority in wear of dark-colored over white paints, the dark paints as a class being much more stable, chemically, than the whites. And this difference in wear is the more striking when we consider that the whites, because of their reflecting character, are largely immune from the effect of the sun's rays.

I have dwelt at some length upon this matter of chemical stability because it affords a logical line for a general classification into two main divisions and the evidence afforded by the remarkable wear of lampblack, graphite and other absolutely inert substances, together with the superiority of silica over whiting when used in large proportion, is a practical demonstration of the validity of the old rule: "Oil is the life of a paint." It might be objected that the inertness of those pigments mentioned extends beyond the possibility of reaction with the oil so far that the deduction would be better if drawn from less extreme premises, but it should be emphasized here that no pigment can undergo change within the paint coat without affecting the oil. We are all, I think, prone to consider the oil as it is when liquid, but in the coat it is solid and after the coat has weathered it is brittle. So, excluding all reference to saponifying action, it is plain that a carbonate undergoing reaction with the sulphur dioxide in coal smoke or with hydrogen sulphide will evolve a gas and rupture the stiff paint film above the particle of pigment, leaving a tiny pit or a hole. In like fashion substances which change chemically without evolution of gas must, as they change their specific gravity, alter in bulk and lose their intimate contact with the oil walls of the cells surrounding the particles.

As to paints which form soaps or otherwise react directly with the oil, the resultant compounds are invariably less elastic than a naturally dried oil film and they are necessarily unstable, the oil acids being weak. The results of their use in large proportions are made apparent by minute checking and flaking of the coat. A paint made with linseed oil and a non-reactive pigment will never do either.

Comparison of different pigments is rendered difficult by their very great variation in fineness. Other things being equal, Mr. Job has shown that wear is dependent upon fineness for paints containing one pigment only, but paints made only from ultimately fine substances do not brush properly and it is convenient to correct this behavior by adding about ten per cent. of a coarser material, preferably of a distinctly crystalline and stable nature. Such additions have no apparent harmful influence; indeed, at least one very valuable pigment, zinc oxide, is greatly improved by the addition of a very considerable amount of coarse material. In this case its functions seem to be those of crushed stone or gravel in concrete. Coarse pigment alone will not make a paint, apparently, because the oil and pigment, having different coefficients of expansion actually tear apart. To preserve the bond between them the interstices must be filled with incomparably finer pigment which prevents the formation of these centers of local strain. There seems to be no limit to the degree of fineness desirable; the finer the better for the obscuring pigment, provided always, it is not reactive. For the coarser parts, there is, however, a maximum which is not far from $\frac{1}{100}$ of an inch.

Solubility in water is a third line of differentiation. Unlike some investigators, I believe that an appreciable degree of solubility is unqualifiedly objectionable. We have but two common paint ingredients of this kind, gypsum and the incidental zinc sulphate in some compound paints.

I have endeavored briefly to point out those characteristics which seem to be the controlling influences in pigment wear, and from those I would suggest the following rule for estimating the chance for deleterious effect from a certain ingredient:

The wear of a paint depends upon the fineness and chemical stability of its predominant pigment. This statement is made in no dogmatic spirit. Special conditions require special formulæ. A paint may give perfect satisfaction in one locality and fail entirely in another, but I submit the above generalization for your criticism, believing that, considering all conditions, it is true.

The reactive pigments unquestionably have a value, but their effect when used in amount sufficient to render their influence predominant is not, in my opinion, satisfactory.

Lack of time prevents any mention of oils. Fortunately, there is, at present, no great difference of opinion on this point.

To close, I do not regard any recognized paint material as *per se* deleterious. It may become so when used in excess of its advantageous proportion and just what that proportion is varies with the nature of the other ingredients and with their amount.

DISCUSSION.

Mr. Cheesma

Mr. F. P. Cheesman.—As Mr. Hughes is mainly interested in the pigments entering into the makeup of paints it seems best that I should confine myself largely to the vehicles used.

While linseed oil is not an ideal paint vehicle, it is still the best that has been discovered, but a mistake is sometimes made in specifying the use of boiled linseed oil instead of raw. I do not favor the use of boiled oil under any conditions as it does not give the same durability as raw will when used in connection with a drier selected with special reference to the pigment or pigments used.

Louis E. Andes states in his book on Drying Oils, page 219, "Boiled oil made in the cold, whether with liquid driers or with soluble driers, produces a somewhat softer coating than when made by heating, but gives a more durable coating of paint, because there has been no decomposition of the linseed oil, such as takes place by heating at high temperatures. In former times, when different views were held in regard to the formation of boiled oil and the drying process, products made simply by mixing with liquid driers were not regarded as boiled oil, for in the preparation of boiled oil higher temperature and the introduction of oxygen whether by the action of air or the reduction of added metallic oxides rich in oxygen, are absolutely necessary. This opinion is now obsolete; any linseed oil made active, by whatever process, is regarded as boiled oil."

Please do not forget that a great deal depends upon the kind of drier used. A paint in which the principle pigment is oxide of iron requires a different drier from a carbon pigment, and lead or zinc pigments also require different driers. It cannot be too strongly emphasized that the character of the drier and the amount used has a great influence on the durability of the paint. If we could keep the paint protected until dry and use raw linseed oil only, we would have the greatest durability. The addition of any form of drier to linseed oil shortens its life, but the conditions that we are

Mr. Cheesman. compelled to work under make it a necessary evil to use driers in some form and the technical paint maker should be allowed to use raw linseed oil as a base, then adding such driers as his knowledge of his business assures him are the best to use in connection with the pigments and the character of the work.

One dangerous vehicle used in some paints is carbon bisulphide and the use of it should be prohibited under heavy penalty by law, as it is a deadly poison producing when inhaled paralysis, idiocy and death. A case recently came to my notice where eight painters working out in the open air on large bridge girders were overcome by the vapor coming from a certain proprietary paint used by them and it was over a week before they could resume work—had they been working in a confined space it would probably have caused their death. I quote from M. P. Wood on Rustless Coatings, page 110—"A supposed better class of asphaltum paints or so-called varnishes, similar to the 'Maltha,' 'P. and B.,' and other trademark designations, are freely marketed as superior paint products. They are in no sense varnishes, but simply the above-mentioned class of pigment substances, mixed with bisulphide of carbon, benzine and other uncertain hydrocarbon liquids and oils, the latter often containing more rosin oil than linseed oil. They are not compounded by heat, as all true varnishes are. They have had an extended trial for many years on important ferric structures—naval, hydraulic and other work, only to fail after a brief exposure. Wherever placed in competition with other carbon or metallic-base coatings they are invariably found low in the column of merit. As a rule they spread easily and show well at first, but when the volatiles have evaporated, especially if they have been subjected to a moderate heat test, 140° to 180° F., they become brittle, turn brown, crumble and are easily removed. The application of paints containing bisulphide of carbon is attended with extreme danger from fire, even on external exposures. The vapor of bisulphide is very explosive at low temperature, also disastrously injurious to the painters or others breathing it during the application of the paint in any confined space and only moderately less so in the open air."

An account of its application to water-mains, where it resulted in the insanity and death of a number of the painters and workmen engaged in painting and laying the pipes, also in the utter failure

Mr. Cheesman.

of the coating to protect the same pipes from corrosion, is given in "Transactions American Society Mechanical Engineers, Vol. XVI, 1895, Paper 637. Also in Engineering News, Feb. 7, 1895, and April 4, 1895. A further demonstration of the inferiority of these asphaltum paints in competition with other oil paints and black varnishes is given in a series of tests made by Mr. Max Toltz, C. E. The report was read before the Society of Civil Engineers, St. Paul, Minn., and reported in the Journal of the Association of Engineering Societies, 1897. It was also briefly referred to in "Transactions American Society Mechanical Engineers," May, 1901. It seems to me that a manufacturer who puts a product on the market containing a deadly poison and who does not warn the user (by labels or otherwise) of the character of the product and its deadly effect could be made to pay heavy damages without any special law being required.

As linseed oil is now the cheapest vegetable oil that we have, there is no danger at this time of its being adulterated with cottonseed or corn oil. The mineral oils are the principal reducers of cost to-day and if they would use only benzine in moderate quantities as a cheapener the results would not be so bad as using the many substitutes for turpentine, most of them containing kerosene. Turpentine is, of course, a detriment to a paint, and for exterior exposure should only be used in the drier and between using a drier made of pure turpentine and rosin gums and one made from benzine and straight Kauri gum, I would for the sake of durability select the benzine drier. Water is out of place in a paint where durability is desired and any paint containing more than 2 per cent. of water should be rejected.

The old saying "That one man's meat is another man's poison" is especially true as applied to paints, as the pigments used in one location with good results may become deleterious ingredients when used in another locality or for a different class of work, as for instance—50 per cent. of zinc or even more may be used with good results along the sea coast, but in the interior it will very probably crack the paint and cause peeling. In this connection, while I am on the subject of zinc it might be well to mention a fact which is not very well known and that is that zinc when made direct from the ore (as most of the zinc is in the United States) and used straight in a paint it will as a rule chalk, but the same zinc

Mr. Cheesman. used in not excessive proportions in combination with lead and other pigments will not chalk.

The paint maker who manufactures his paint on one formula for use over the entire country or to spread over the entire earth, labors at a great disadvantage as compared with the technical paintmaker, who manufactures each particular lot of paint to suit special wants, as it is impossible to use one formula successfully when the paint is applied under varying conditions. Hence a particular brand of ready mixed paint that wears well in New York City and vicinity on account of the large percentage of zinc in it, has been known to give poor results when used for instance in Binghamton, N. Y., the paint in that climate cracking and peeling badly.

In conclusion I might state that there are, however, two ingredients that can always be used successfully in paint, wherever applied, but frequently, alas, they are forgotten in the specifications, and those two ingredients are brains and experience. If the engineer, architect or chemist in preparing his specifications would occasionally take council with the experienced paint doctor, their paint specifications would not look as ridiculous as they frequently do to the paint maker, and I desire to extend my thanks to such men as Dr. Dudley who invite criticism and suggestions from paint makers before they adopt a paint specification.

Sometime ago we were asked to bid by a large freight car manufacturing concern on their paint specification for a black paint. The printed specification called for the use of 85 pounds lamp black with 15 pounds linseed oil to make a ready mixed paint. In bidding we called their attention to what we thought must be a typographical error and bid on 15 pounds lamp black and 85 pounds linseed oil. We were told to bid as per specification, that they had been using this specification for over two years and we were the first that presumed to question the paint knowledge of their chief engineer. We finally convinced them that possibly we did know something about the manufacturing of paints by proving that a flour barrel would hold about 50 pounds of dry lamp black and that 15 pounds of linseed oil was just two gallons, and by taking that quantity of linseed oil you could hardly sprinkle 85 pounds lamp black much less reduce it to a liquid paint. They changed their specification but we have not as yet received any thanks from their board of directors.

Mr. Cheesman.

There is a constant advance being made in the science of paint and varnish making, and while the paint maker may not be as good as he thinks he is, neither is he as bad as many of the laymen here thinks he is. For instance—rosin gum varnishes made to-day with Chinese wood oil are as durable as were many grades of Kauri gum varnishes five years ago when we did not know the value of wood oil in connection with rosin.

There is one pigment I would suggest that you keep out of your specifications, and that is ochre, as I have yet to see a durable paint made with ochre as the principal pigment, and as far as possible use pigments that have been purified and rendered largely inert by a heat treatment.

Mr. Thompson.

Mr. G. W. Thompson.—Mr. Chairman, I should like very much to discuss this paper in detail; and it is with the strongest effort on my part that I am restrained, because there are so many points in it that to do justice to them would take up more time than I think this occasion permits. I want, however, to refer to one particular point in the paper, and that is the reference to the question of inert pigments in protective coatings. Now we have heard the term inert pigment used a great deal, and yet unfortunately it has been used very loosely. And without any desire to criticize Mr. Hughes, I think Mr. Hughes has used the term inert pigment loosely; because a pigment may be inert chemically and active electrolytically. We listened last night to an exceedingly interesting paper on the corrosion of iron and we have had another interesting talk this morning on the same subject, and we have heard that mill-scale is a deleterious substance to have on iron because it is active electrolytically, and yet mill-scale itself is quite inert chemically. Now I simply want to add to this a further suggestion for Mr. Cushman and Mr. Walker and to others who are investigating the corrosion of iron, that they make experiments to discover the relative electrolytic activity of various pigments in relation to iron. While I do not wish to give any positive results here to-day, I wish to speak of certain experiments which I have recently had made. A series of bottles, all of the same size, were arranged with two-hole stoppers so that a current of air could be drawn rapidly through the whole series, with glass tubes connecting one bottle to the next bottle in the series, and one end of each glass tube running down to the bottom of the liquid

Mr. Thompson. which was subsequently placed in these bottles so as to produce the greatest amount of agitation. The air being drawn through the upper end of the tube was forced up through the liquid. Then I placed in each bottle 90 cubic centimeters of distilled water, also a piece of steel of standard size cut from a standard piece of sheet steel, carefully cleaned as could be without roughing up the surface. I ran two blanks, one at each end of the series, that is with water alone and no pigment. Then in these bottles, in addition to the piece of steel, were placed quantities of pigments corresponding to 5 cubic centimeters; that is to say, an amount was taken equal to 5 grams multiplied by the specific gravity of the pigment, so that we had practically 5 cubic centimeters of pigment. The bottles were then connected with an aspirator and the air drawn through. The air was drawn through so rapidly that it was believed that each bottle would receive practically the same charge of air and the carbonic acid gas contained therein. After twenty-six hours these pieces of steel were taken out and as carefully cleaned by rubbing with the fingers and muslin as could be done to remove the pigments and to remove any rust that might have been formed, and then they were dried and weighed and the percentage of loss was noted. I will give you this much in the way of figures: the percentage loss of blank No. 1 was 1.12 per cent.; of blank No. 2, at the other end of the series, was 1.07 per cent.—practically identical. The remarkable thing appears to be that some of the pigments had inhibited the oxidation; because, without referring to the pigments—this is a matter of experiment, and I do not wish to offer this as in any sense final—with one pigment the percentage of loss was 0.29 per cent. in one test; and in another, 0.37 per cent., showing a large inhibition. On the other hand, with one pigment, there was a loss of two per cent. —an increase of nearly one hundred per cent. as compared with the loss with simply water and jar. With certain other pigments the figures obtained were practically identical with the loss which came from the simple action of the air and the water alone. Now it reverts back to the proposition which occurred in Mr. Hughes' paper, which I contend involved a loose expression, that there may be some pigments which may be active chemically, as we consider them, and yet be inactive electrolytically. So, there may be some pigments which are inactive chemically and active electrolytically. And I would suggest that the committee on the corrosion of iron investigate this matter and see whether they cannot, with the facilities that they have in their possession, find out which pigments are active electrolytically and whether possibly there may not be some pigments that act very much like chromic acid and nitric acid gas, which produce an inert condition on the surface of metal. **Mr. Thompson.**

MR. A. S. CUSHMAN.—May I contribute a few words more. No one has said anything about the iron that is to be covered with paint. Mr. Hughes stated in his paper that iron was a very good substance to test paints on. If a bad iron is to be compared with a good iron there is another complexity that arises, besides those which have been mentioned such as changes of climate and locality. It seeems to me, however, that Committee E should pay special attention to the quality of the metal painted before they form a judgment upon the results obtained in the tests. If it is found that one paint has failed under water and the paint is condemned on that account, the fault may not after all have been in the paint but in the particular sheet that the paint was spread on. I have seen sheets that have come off the same pile, made of the same metal, which were undoubtedly different in their rust resisting character. Now all paints probably let water and oxygen through to a greater or less extent. If the plates or sheets that have been covered vary in their rust resisting quality, it is not necessarily a question of the paint, it may be the metal which is at fault. **Mr. Cushman.**

MR. THOMPSON.—In these plate tests there were nine tests, a different plate being taken for each test, the idea being that though having a number of plates we would in that way have an average in the case of each paint. **Mr. Thompson.**

MR. S. S. VOORHEES.—In reply to Mr. Cushman's remarks, there has been a great deal brought out at this meeting which we had in a measure realized, but it has been more thoroughly crystallized. One point Mr. Cushman made in regard to these plate tests, the immersion in water. He is mistaken there. They are not immersed in water but exposed to the air, though the conditions of electric action exist undoubtedly, even in the atmosphere. As Mr. Thompson has brought out, each paint has been applied to nine different panels. The average effect of electrolytic **Mr. Voorhees.**

Mr. Voorhees action on these nine different plates will be investigated along the lines which have been suggested. These three methods of determining electrolytic action will enable us to take account of this point. The area of the sheets, however, is so large, that segregation can readily exist on nine square feet of surface to a marked degree. It is probable that the whole surface will not be affected alike. The further we go the more the papers presented here to-day seem to emphasize the value of the tests which we have started. The many conditions which have been tabulated carefully and accurately will give, as they are followed, information which will, I feel, be of much value. The point that Mr. Cheesman brought out on the preparation of surfaces has been noted. The method of applying has been noted. In fact, as stated in the report, it seems as if there has been a great deal more brought out of this series of tests than was originally planned.

Mr. McNaughton. MR. MALCOLM MCNAUGHTON.—One reason, perhaps, for the lack of durability of linseed oil coats not touched upon in the paper is the fact that linseed oil is spread out anywhere from three to four thousand square feet per gallon, as against three to six hundred square feet for pigment paints.

Mr. Wickhorst. MR. M. H. WICKHORST.—As I look at the matter it is mostly a question of thickness of coating. If we put on one coat of linseed oil and then two coats of paint we haven't as thick a coating as if we put on one coat of paint and then two more coats of paint. I might go back to an experience of painting engine tanks. The C., B. & Q. Railroad during the hard times of 1894 wanted to save money; and one way they did it during that time was to cut down the extra coating that had been applied on the engine tanks. It was reduced to about three-coat work on new metal. It was noticed that those tanks rusted very badly in about a year, except that the letters remained in good shape; but it so happened that those letters had two extra coats. I have samples of sign boards where there is a white background and black letters, where the background is all gone and the lettering only remains. On other boards the material has been reversed and we have a black background and white lettering. The letters in all cases remain in good shape. There is a certain minimum thickness of good durable material that is necessary to withstand the action of the atmosphere, moisture and light. Assuming the vehicle to consist mostly of pure linseed oil it looks to me to be rather a matter of thickness of material applied than whether it is linseed oil or paint. **Mr. Wickhorst.**

Mr. Marshall. MR. WILLIAM MARSHALL.—Mr. Cheesman in his remarks frequently used the words "boiled oil." Those of us who are more or less familiar with that subject know that there are boiled oils and boiled oils. And I presume that a great deal of trouble comes from the difference in the treatment of oil in making it into boiled oil. Nearly every oil boiler has a different method, a different preparation of driers, and different kinds of driers. But I think perhaps the greatest difficulty in applying oil to metal is the difference between applying it to wood or metal. When you apply a priming coat to wood, the wood immediately absorbs it and it clings to it. When you apply a priming coat of oil to iron, there is hardly any power of absorption or clinging. I have given considerable thought to this and spoke of it at one time in the New York Railroad Club. I also had correspondence with some of the Pennsylvania Railroad officials suggesting that where parts can be assembled—there is a great difficulty in getting my theory applied to bridge work or any large work—to subject them to any degree of heat over 212° F. before applying the priming coat of oil. I believe that oil with no driers in this case would be better, because if the heat could be prolonged the heat would dry the oil better than the oxides put into the oil to make it dry; but if either raw or boiled linseed oil is applied when the pores of the metal are open so that the oil enters into and permeates the whole of the surface it is then ready for subsequent coats of paint and will hold up the same as well as wood. I believe this would solve to a large extent the problem of iron corrosion.

Mr. Heckel. MR. G. B. HECKEL.—I want to say one or two words, not by way of criticism, but to call the attention of the members here to one important fact. Mention was made in Mr. Cheesman's paper of the deteriorating quality of linseed oil due to exhaustion of the soil, etc. According to the authorities of the North Dakota Agricultural Station, some of whom have been making extensive experiments in this line, I learn that the deterioration both in the seed and the crop is due to a disease, and they have succeeded in immunizing the seed and planting in exhausted soil and raising again an increased crop of good seed. I think that is a fact worth noting here.

Mr. Skinner. MR. C. E. SKINNER.—The fineness of the pigment has been referred to, and I would just like to mention that recently two materials have been brought to my attention which are of exceeding fineness, and one of them is under investigation with the object in view of using it as a pigment; I have not heard whether the other is to be tried as a pigment or not. They are both electric furnace products. One is deflocculated graphite, a paper concerning which will be read at the American Institute of Electrical Engineers this coming week at Niagara Falls. This material is so fine that when in solution it passes readily through filter paper. If the fineness of the pigment is an item, that should prove a good material. The other is monoxide of silicon, which is also of exceeding fineness and has in a very marked degree the property of opaqueness, although it is of a rather light color.

Mr. Job. MR. ROBERT JOB (by letter).—The statement has been made that yellow ochre makes poor wearing paint. From my experience this has not been the case, for one paint containing a yellow ochre base in general service upon bridges during a period of about ten years had the reputation of being the most durable paint ever used upon the lines for that purpose. Other instances of the same nature also might be cited. In these instances the oil was pure linseed with a small proportion of Japan drier.

THE PHYSICAL TESTING OF OIL VARNISHES.

By J. Cruickshank Smith.

There has been a noteworthy increase during recent years in the attention devoted by technical chemists and testing engineers to the physical or mechanical properties of paints, varnishes and other protective materials. This is largely due to the growing appreciation of the fact that in actual service and under the conditions of prolonged exposure to the atmosphere, moisture, etc., the durability or life of protective coatings depends as much on physical laws as on chemical ones, and further that the physical state or condition of the coatings has an important bearing on their liability or the reverse to chemical influences both external and internal.

So far as one is able to gather, investigations and researches into the testing and valuation of oil varnishes have in the past been of a very meagre description. Search through the scientific and technical literature of the last ten years has failed to unearth anything of definite practical utility in this direction, which is the more to be wondered at when one considers the considerable technical importance of oil varnishes and the frequent necessity for determining their intrinsic value either as decorative agents or as protective materials.

There are many persons who look upon chemical analysis with feelings of greater veneration than the occasion always warrants. Regarded from the point of view of *technical valuation* or *testing*, analysis is only a means to an end, that end being to enable the analyst to form an opinion as to whether the material under examination is likely to behave satisfactorily in use. Analysis, however, only tells what a substance consists of or what a material contains, and it is a well known fact that so far as oil varnishes are concerned we may learn from the chemist how much oil, how much turpentine, how much gum a given varnish contains, we may even learn from him whether the gum consists of animé or kauri or rosin, and yet we may be quite unable even with this knowledge to form any reliable opinion on the subject of the wearing properties of the varnish in question. It must not be imagined that I cast any slight on the analytical chemist in the matter of testing materials. I am very far from doing so. My point is that it is not always *composition* that determines the technical value of an article. Other factors besides composition come into play and it is the determination and if need be the measurement of these factors which I include in the expression *testing*.

It has fallen to my lot during the last half dozen years or so to examine with some degree of care samples of oil varnishes representing many thousand gallons of the standard manufactures of the leading British makers, and it has frequently occurred to me how valuable it would be to the user or purchaser of large quantities of varnish if he were in a position to form a fairly reliable judgment as to the quality and wearing capacity of a given sample without having to await the result of some long exposure test. Consequently I have made a practice of applying a series of physical tests to such samples of oil varnish as came under my notice, and having tabulated the results somewhat carefully I have pleasure in making these public, in the hope that the facts I state may prove useful and suggestive, and may form the starting point for other observers who may be able to augment what I feel to be merely an initial and more or less pioneer investigation.

There is an objection to chemical tests as the sole means of determining the value of oil varnishes which may be pointed out. It is that varnish manufacturing practice is not nowadays the simple guileless process it was in "the good old days." Unhappily science holds out helping hands both to the just and to the unjust, and it sometimes happens that the latter class are less disinclined to refuse the proffered aid than the former. Processes are in existence for hardening rosin and for enabling compounds of lime and other metallic bases with rosin to be incorporated in oil varnishes. Such methods may be bad or they may not, but they increase enormously the difficulty of the consultant who is compelled with only chemical data at his disposal to form an opinion on the suitability or durability of a particular varnish for a particular piece of work.

Therefore it is that the tendency appears to work along the lines of physical tests. These tests may be roughly divided into two groups. The first group includes those tests of a strictly scientific nature, such as the determination of specific gravity, viscosity, optical activity, solubility constants and the like (*vide* A. Tixier's "Studies on Varnishes," *Moniteur Scientifique*, 1904). It has also been sought to measure the hardness and toughness of varnish films in terms of some definite standard. Quite recently Professor Baily and Dr. A. P. Laurie, of Edinburgh, read a communication before the Royal Scottish Society of Arts on a physical method of testing varnishes, the object of which is to reduce to a definite standard the qualities of hardness and toughness. Professor Baily and Dr. Laurie have devised an apparatus which they claim attains this object. The apparatus consists of a blunt steel point ground to a certain radius, upon which various pressures can be put by means of a spiral spring. The varnish to be tested is painted on glass, and is allowed to dry. The steel point is drawn along the glass, and the pressure increased until the surface of the varnish is film scratched. As the pressure is known, a measure of the hardness and toughness of the varnish film is obtained. The criticism one is inclined to pass on Baily and Laurie's method is that it would appear to be essential, in order to obtain concordant results by the method outlined above, that some standard method of obtaining the dry varnish film should be adopted, as it is well known that samples of the same varnish do not dry uniformly under varying conditions, and unless errors due to variations in time, temperature and humidity are eliminated it is difficult to see how the results obtained by this method can be of real practical utility for the valuation of varnishes.

The second group of physical tests includes those which are based on the theory that the capacity of varnish films to resist the influences they may be expected to undergo in actual use over a considerable period of time can be estimated with fair accuracy by exposing the films to severe but rigidly controlled conditions for a short period of time and then examining their physical condition.

Drying tests for varnishes are frequently very misleading on account of the conditions varying, therefore in the three series of drying tests to be described the utmost care was taken to ensure as far as possible uniformity in the drying conditions.

A.—NATURAL DRYING TEST.

This test is undertaken in order to determine the rate of drying of the varnish under normal conditions and the conditions of the varnish film after drying. Drying under normal conditions with free access of air is by no means easy to ensure, as a very little consideration will show. The time of drying can be regulated. The temperature can be regulated. But it is a more difficult matter to ensure uniformity as regards the dryness or humidity of the atmosphere. Numerous experiments have proved conclusively that this question of humidity of the atmosphere is at the root of many of the abnormalities met with in the drying of a varnish. The so-called drying of a varnish depends partly on the evaporation of the solvent in the varnish and partly on the oxidizing action of the air. The presence of moisture in the air at once interferes both with the evaporation of the turpentine and the oxidation of the oil. All free drying tests should therefore be conducted in a dry airy chamber which can be maintained at a temperature of 55°–60° F.

The varnish is poured on a clean dry glass slip 2 x 6 inches in sufficient quantity to cover three-quarters of the slip. The various slips are then stood vertically upright for five minutes in order that excess of varnish may drain off. Any drops that adhere to the edges are carefully removed with blotting paper and the slips are then placed on racks inclined at an angle of 10° from the horizontal. The temperature is maintained at as near 60° F. as possible, not more than 2° variation either way being permissible, for 24 hours. No ordinary oak, copal or carriage varnish of good quality will be sensibly tacky to the touch after 12 or 14 hours. Twelve hours may be regarded as a satisfactory limit for house painters' varnishes and eighteen hours for coach painters' and extra pale varnishes. After drying, the films should be transparent, free from specks, lustrous and hard, yet elastic. Out of a series of 124 varnish samples examined, 21 were rejected as not satisfactorily passing this test. Of the 21 ten were rejected for obvious faults such as lack of lustre, liability to bloom, etc.; the remaining 11 were subjected to exposure tests with the result that 9 proved unsatisfactory, while two were satisfactory. The balance of evidence then in regard to this test goes to show that a varnish which does not comply with the requirements of the test will *most probably* be unsatisfactory in use.

B.—FORCED DRYING TEST.

The question has been discussed whether in the case of oil varnishes the results of a short exposure under extreme conditions can be utilized in order to give information as to the probable results of prolonged exposure under ordinary conditions. The results of many experiments appear to indicate that in a general way they can.

The test samples are poured on to glass slips as in A, and the slips are drained vertically for five minutes. They are then heated for 24 hours in a hot-air chamber, through which circulates a steady stream of pure dry air maintained at 100° C. It is surprising how this test separates varnishes of different quality, and a close relation appears to exist between durability and capacity to stand this test. In applying this test it is well to always employ two or three control samples. Thus one ought to conduct four duplicate experiments with the same varnish. If three concordant results are obtained they may be taken as correct, but if less than 75 per cent. of the samples emerge successfully from the ordeal either they must be condemned or the test must be repeated. The result that one looks for in a varnish film after exposure to this test, is a hard, dry, transparent and tough film, free from cracks, and coming off in ribbon-like scales when scraped with a steel point. Powdering under the tool is a fault, so is too soft a result. Fissures and cracks should be carefully looked for, not only with the naked eye but under a hand lens or low power microscope. The following are the tabulated results of experiments, extending over a period of five years:

1. Fifty-three sets of 4 samples each of oak varnish yielded 39 results in which the test was satisfactory for at least three of the four samples. Exposure tests on these 39 samples proved that 32 were reasonably durable; 4 were doubtful (exhibiting after exposure certain slight faults); 3 proved unsatisfactory on exposure. Each of the 53 samples had already passed test A satisfactorily.
2. Twenty-seven sets of 4 samples each of copal oak varnish yielded 19 results in which the test was satisfactory for at least three of the four samples. Exposure tests on these 19 samples resulted in 17 proving satisfactory and 2 unsatisfactory.

3. Thirty-four sets of experiments with copal, carriage and body varnishes yielded similar results, only 4 per cent of those samples that passed the test proving unsatisfactory in an exposure test.

It is noteworthy that 89 per cent. of the samples rejected by this test proved unsatisfactory in exposure tests. We are, therefore, justified in concluding that the forced drying test will, if conducted under properly controlled conditions, give the observer a very fair and safe indication of the probable durability of the varnish under examination.

The practical deductions from these results are: (1) that no varnish which has failed to pass the forced drying test will be thoroughly satisfactory in service; (2) that although every varnish that passes the test cannot on that account alone be absolutely depended on to stand a prolonged exposure test, the great majority (about 92 per cent. in the case of lower grade varnishes and about 96 per cent. in the case of high-class varnishes) of those that passed the test emerged successfully from prolonged exposure tests. In most cases the reason for the failures will be found to be due to some abnormality in composition such as excess of driers, presence of rosin, unsaponifiable matter, etc.

C.—AIR-DRYING TEST IN PRESENCE OF PIGMENT.

When the surface of a varnish that is exposed to the air is increased relatively to the total bulk of varnish there is a considerable increase in the rate of drying. This fact may be made use of in testing varnishes. Equal parts by weight of varnish and oxide of zinc are rapidly incorporated by means of a palette knife on a glass slab, and the mixture is painted on a glass slip and exposed to the air under fair drying conditions. Exterior and "elastic" varnishes ought not under these conditions to take more than nine hours to dry. Interior and "hard drying" varnishes may take rather less but not less than 6 hours. The foregoing test may also be made use of to determine the intrinsic coloring power of the varnish.

The exterior characteristics of varnish which should be carefully examined in comparing different samples are brightness and color. Brightness practically means freedom from suspended matter and special attention should be directed to this point as it has been found that the durability of varnish films is greatly interfered with if suspended matter is present even in small traces.

Color should be compared against some definite standard. Varnishes may be conveniently divided into four groups as regards color, viz., extra pale, pale, medium and dark. The palest white copal and French oil varnishes would fall under the first heading. "Pale" varnishes would include the pale copals, pale carriage varnishes, maple and pale oil paper varnishes. "Medium" would include most of the standard copal oaks, darker carriage varnishes, etc., while "dark" would be reserved for a still darker group.

In comparing the color of varnishes use may again be made of dried films on glass slips, the actual determination of the color in comparison with the standard taking place at least 48 hours after the varnish ceases to be tacky. It will be found that many varnishes which are pale in themselves and when first spread out in a thin film darken materially in drying.

I am indebted to the London Borough Polytechnic for details and samples of a simple and practical test worked out in their paint and varnish laboratory and which appears to afford useful information as to the general quality and durability of oil varnishes. This method, which may be conveniently referred to as the black paper test, consists in flowing the samples of varnish under examination on to a non-absorbent black paper with a small brush. The operation of brushing the varnish on to the paper affords the operator an opportunity of examining the flow and setting of the varnish as he can "flow on," "cross" and "lay off" in precisely the same manner that a coach painter does in varnishing a panel. The papers are then hung up in a fairly warm room maintained at an even temperature and examined from time to time during a period of about a fortnight. By the end of that time it is quite easy to detect the more brittle and rosin varnishes from those made with durable gums by creasing with the thumb nail. It is interesting to note how certain varnishes tested in this manner break down under compression more than they do under expansion, that is by reverse folding. The difference in gloss of different varnishes tested in this manner is very marked, and should there be the slightest tendency to bloom, the black surface shows it up instantly. It is conceivable that a combination of this method with the forced drying test already described might give useful results, there being much to recommend the use of a black surface in comparing differences of lustre and surface effects such as blooming, fogging and the like.

May I, in conclusion, say that this paper had been compiled before I perused Mr. Robert Job's valuable paper on the "Practical Testing and Valuation of Japan," and that the British members of The American Society for Testing Materials gladly acknowledge the excellent and practical work which the Society is accomplishing in the region of common-sense technical testing.

DISCUSSION.

Mr. Robert Job (by letter).—Chemical analysis of varnish is of value mainly to the manufacturer who wishes to check up his factory formulæ, or to duplicate the composition of a given sample, and is of less benefit in determining the practical service value of the material, for the reason that in the process of manufacture the properties of the materials may be completely altered. The true value of varnish, from the standpoint of durability, depends upon its ability to resist certain physical conditions, and consequently the natural, and to our mind the ideal method of valuation is by means of a system of physical tests so devised that the ability of the material to withstand each of the deteriorating agencies may be definitely known, and hence its service value determined. We do not lose sight of the fact that chemical reaction may take place among the constituents of the varnish, but we believe that a simple system of tests can be devised which will give the necessary knowledge. **Mr. Job.**

From this brief statement it will be clear that we are heartily in accord with Mr. Smith's plan, and we believe that the methods proposed will form an excellent foundation for the rapid technical valuation of the material.

In the case of our method for testing of Japan drier—to which Mr. Smith has very kindly referred—we derived such satisfactory results in service, that we were convinced that a system of physical testing was equally applicable to valuation of varnish and began some experimentation toward that end, although we were unable to carry the scheme to a definite conclusion owing to pressure of other work.

Mr. A. H. Sabin (by letter).—The following contribution to this subject may perhaps be of interest. It has been the practice of the writer to make the following test on a dry wooden panel of any convenient size—say four or five inches wide. The panel is well varnished and allowed to dry. Then a sponge, wet with water, is laid on it, and it may be inspected from time to time. Usually the sponge test begins at night, say at five o'clock, and the **Mr. Sabin.**

Mr. Sabin. next morning inspection is made at eight o'clock. If the varnish is quite destroyed a fresh test is begun at once and hourly observations made. If, on the other hand, it is not sensibly affected, the test is continued. This is a very quick and severe test. Cheap varnishes containing much rosin are quickly destroyed; only the most durable and weather-proof will stand it. Like all such tests it is well to make it in comparison with some varnish of known quality.

Mr. Voorhees. MR. S. S. VOORHEES (by letter).—The need of a correct interpretation of varnish analysis by physical tests, is made clear in Mr. Smith's paper.

In general the presence of large amounts of rosin and benzine indicates an inferior varnish, while a high grade varnish made from hard fossil gums is indicated by a low acid value, absence of lime and limited amounts of lead and manganese in the ash, Liebermann-Storch reaction on alcoholic extract showing brown to brownish red, with a volatile of pure turpentine. In some cases, however, when the figures show more or less deviation from the above standard, the product appears to be of excellent quality.

So much progress has been made in the manufacture of varnish that it seems to be possible to make a durable product from materials which have been considered inferior. Proper treatment in the manufacture means nearly as much in the finished product as the composition determined by chemical analysis. This is due, in part, to lack of accurate methods for the analysis of such complex mixtures as varnish, and also because chemical analysis does not tell the treatment the material received in the process of manufacture, and finally because the results obtained need to be interpreted by physical and service tests. On this account chemical analysis can not supply the information desired until service and exposure tests furnish the data.

For a comparison of the films it is necessary that variables of time, temperature, moisture, intensity of light, and thickness of film, etc., should be made constant. The first four conditions can be controlled, but the last depends on body or vicosity of the varnish and character of volatile. The temperature of 55° to 60° F., recommended by Mr. Smith in the "Natural Drying Test," is altogether too low for use in this country; unfortunately a temperature of 30° C. (86° F.) is nearer the normal summer conditions in most of our laboratories. It is also possible that other atmospheric conditions affect rate of drying, and consequently condition of film at any fixed period of time. An article by Professor A. H. Sabin which appeared in the Journal of the Society of Chemical Industry for 1906, indicates that ozone may be a more active drying agent than atmospheric oxygen. **Mr. Voorhees.**

The Forced Drying Test recommended by Mr. Smith has been used here in a more or less systematic manner. It is encouraging to note the concordant results obtained by this test.

The test quoted by Mr. Smith as used by the London Borough Polytechnic, should detect bloom, fogging, etc., but the same results are obtained by holding the natural dried film over an opaque black glass. The physical condition of the film either after normal or abnormal exposure can be better tested on the film itself apart from the surface to which it has been applied. A suitable film can be obtained by amalgamating a sheet of tin or terne plate 6 x 6 inches with mercury and either flowing or brushing on one or more coats as desired. The varnish is dried under normal conditions. It does not adhere to the amalgamated surface and can usually be removed intact. The tensile strength, elasticity, porosity, etc., can then be determined after varying conditions of exposure.

There is need for some definite means to measure the hardness and toughness of the film formed under fixed conditions. If the instrument devised by Professor Baily and Doctor Laurie gives this information, a decided step has been gained. Until, however, accurate information is obtained showing that a high grade durable varnish can be made containing appreciable amounts of other substances than linseed oil, turpentine, hard fossil rosins and metallic oxides used in the driers, it will be necessary to exclude these substances.

Mr. J. Cruickshank Smith (by letter).—I am obliged to those gentlemen who have been good enough to criticize my paper, and I am glad to observe that, speaking broadly, they agrée that the elaboration of a series of physical tests for varnish films is to be desired. As I point out in the paper, I make no claim to treat the subject exhaustively, and if, when the paper and discussion come before the wider audience of the members as a whole through the medium of the printed proceedings, interest is stimulated in **Mr. Smith.**

Mr. Smith. the question of the mechanical testing of varnish films, and additional light is thrown on the problems connected with the subject, my main object will have been achieved.

It would appear to me that, if it be generally agreed that the forced drying test is of real practical value as throwing light on the probable wearing power of varnish in actual service, the problem before us is of a twofold nature. First, there must be worked out a physical or mechanical test, or a series of such tests, whereby the hardness, toughness and elasticity of the films may be measured in terms of some definite standard. This will involve a critical survey of such methods as that of Bailey and Laurie, as well as those based on the determination of the moduli of torsion and elasticity (c. f. Mills and Gray, "Testing Colloids," Journal of Soc. Chem. Ind., XXIII, 526). Secondly, there must be framed precise specifications as to the conditions under which the films of varnish are to be prepared. Investigation concerning the latter problem offers abundant opportunities for experiment and observation. I am not sure that I altogether agree with Mr. Voorhees when he says that it is necessary that the thickness of the films of varnish should be made uniform. The thickness of the film will depend upon the viscosity of the varnish, which again will be dependent upon the composition and mode of manufacture, conditions which I understand we are agreed to leave out of consideration. So long as the films of different varnishes are prepared under precisely identical and standard conditions it seems to me that the thickness is one of those properties which we ought to measure, and thereby endeavor to form an opinion as to whether a viscous varnish is tougher, harder and more elastic than a less viscous one.

I do not mention the figures 55° to 60° F. for the natural drying test because they represent the normal summer temperature in Britain (which they do not), but because I have formed the opinion that the normal drying power of a varnish which is to be used under all sorts of conditions as to temperature in actual service is most satisfactorily determined between the limits stated. It is manifest, however, that there may be wide divergences of personal views on the point, and I am indebted to Mr. Voorhees for his suggestive criticism.

THE PHYSICAL PROPERTIES OF PAINT FILMS.

By R. S. Perry.

This discussion will deal particularly with the dried layer of paint, or "the paint coating" and the services that this paint coating should render in resisting the decay of the structural material it protects. The word "paint" will be used to refer to the liquid material—while the expression "paint coating" will be confined to the final layer of dried paint, which is the vital subject under examination. White paints only and the materials entering into their composition will be considered. The durability of the film of linseed oil holding the paint together, is the life of the coating.

A word in explanation—when the liquid paint drys—as the painter says—or, in chemical language, is oxidized to an apparently hard mass, the viscous linolein of the oil is converted into the rubber-like solid linoxin. This accommodating elastic binder with its smooth surface, when supported by the proper pigments, acts as a seal, not only to protect the structure beneath from decay, but also its own inner mass from disintegration due to over-oxidation. The properly prepared coating thus wears away from surface oxidation and this gives a maximum life to the paint. Any combination of pigments that tends to shorten instead of prolong the surface life is to be condemned. It is to be particularly noted that when this film of linoxin becomes entirely oxidized it is a worthless porous or chalky material, which, while apparently retaining its original integrity, is admitting destructive agencies to the structure beneath. If the oil film in the paint coating chalks or pulverizes throughtout in advance of reasonable surface wear or oxidation, then the life of the paint coating is just so much shortened.

No one pigment is complete in itself, but the manufacturer can balance the virtues of one against the deficiencies of the other to obtain all the required characteristics in his blended pigment body. Certain important pigments are not only deficient in certain requirements but have direct injurious action upon the paint coating, which injurious action the addition of subordinate pigments will often modify and sometimes practically prevent. Corroded white lead, for example, while to-day a most prominent and useful material for paint, has defects which, beyond all other pigments, the manufacturer must overcome. The weak point of carbonate white lead is its alkaline nature, causing gradual progressive attack upon the linseed oil and other materials of the paint coating. This action is cumulative: if the chemical activity of each particle be supported by close proximity of the other lead particles, chemical action of mass ensues, and therefore the extension of the white lead pigment in the paint by the addition of a proper amount of subordinate inert pigment to separate its particles is of decided assistance in mitigating the deteriorating action of that medium.

The more opaque pigments are six:

Basic lead carbonate (or white lead),
Basic lead sulphate (or sublimed white lead),
Zinc oxide,
Lithopone,
Zinc leads,
Leaded zincs.

The less opaque or reinforcing pigments are:

Whiting (calcium carbonate),
Asbestine (talcose hydro-silicate of magnesia),
Barytes (natural sulphate of barium),
China and other clays (hydro-silicate of alumina),
Blanc fixe precipitate $BaSO_4$,
$\left.\begin{array}{l}\text{Gypsum}\\ \text{Terra alba}\end{array}\right\}$ (Hydrated sulphate calcium),
Silex (or silica) including infusorial earths, etc.,
Mineral white (calcium carbonate),
Sulphate of calcium (pearl finish).

The subordinate pigments incorporate properly with linseed oil. The natural, or mineral, pigments of this group yield particles that will average in size with determining particles of white lead. The chemical, or artificial products are intermediate in size between the white lead and the sublimed pigments. It will therefore be seen that considerable latitude is possible in the choice of pigments as regards their size of particles. The aim of the scientific manufacturer is to make a product which will fulfil the requirements of the liquid paint in the can and will proximate as closely as possible the ideal coating when applied. The liquid paint must have the following properties:

(1) Covering or spreading power.
(2) Proper grading of pigment.
(3) Holding-up properties.
(4) Brushing out.
(5) Non-setting.
(6) Consistency or viscosity.

As we are dealing primarily with the dried coating only a brief discussion of these properties of the liquid paint is necessary.

Covering or Spreading.—The paint must spread over a reasonably large area when brushed out (350 to 450 square feet). Spreading varies directly with the size or fineness of the particles of pigments in the paint.

Proper grading of pigment contents.—A limited proportion of the pigment must be coarse enough and of the proper physical form to give what the skilled painter calls, proper tooth, or proper feel under the brush. The rest of the pigment should be fine in order to furnish the other necessary requirements of the liquid paint. White lead, silica and silicates, barytes, are valuable in furnishing this tooth.

Holding-up.—After the paint is stirred up the pigment should remain evenly in suspension and not settle too rapidly, so that the painter may apply uniform proportions of vehicle and solid matter on all portions of the work. Zinc oxide, lithopone, sublimed lead and asbestine easily lead in this while white lead is most defective.

Brushing-out.—The paint should be so compounded that when applied in liquid form it will neither run nor slick, yet will flow out easily without showing brush marks. In this property white lead particularly leads, either in combination or alone. In a machine mixed paint this is obtained by so blending the pigments that the particles average smaller than $\frac{1}{400}$ in. in size.

Non-settling.—The paint must be so compounded that it will not settle hard in the botton of the package. Here again the settling qualities of each pigment being known, the modern factory man scientifically compounds his paints. In this property also white lead is most defective.

Consistency.—The liquid paint should be of a consistency which experienced painters well know and recognize—such that it will neither run off the brush too quickly, nor too thickly—but evenly and smoothly.

The following are the characteristic properties of the ideal coating:

(1) Elasticity.
(2) Adhesive power.
(3) Uniformity.
(4) Sealing quality, or imperviousness.
(5) Opaqueness or obscuring power.
(6) Freedom from internal strains.

Elasticity.—The ideal coating should have sufficient elasticity to allow for the expansion of any material which it is to cover.

Adhesion.—The coating should adhere with infinite closeness to the surface to be protected.

Uniformity.—The dried coating should be absolutely uniform in its composition.

Sealing qualities.—The ideal coating would absolutely exclude from the surface to be protected all agencies of decay—such as water, atmosphere, products of combustion, such as chimney gas with their sulfurous acids, carbonic acid, etc.

Opacity or obscuring power.—This really falls under the heading of sealing because it is essential that the protective coating should contain materials of sufficient opaqueness to entirely hide the surface, thus protecting it and also materially shielding the hardened vehicle of the paint itself from the actinic, or chemical destructive rays of the sun.

Internal Strains.—The ideal dried paint coating would have no areas of unequal stress.

SCIENTIFIC PRECISION AND ACCURACY.

The writer has been greatly impressed with the advantages which would accrue to the paint manufacturer who is desirous of perfecting his product could he have at hand reliable physical data to guide him in his work. Unfortunately, up to this time, this important field has been practically neglected, the little data obtainable, resulting from more or less crude experimentation, seems to be, to say the least, faulty and unsatisfactory, so that he who today begins a scientific investigation of the physical properties of these pigments is like the sailor who embarks on an unknown sea without chart or course. The first great obstacle that the investigator encounters in beginning this work is the difficulty (to borrow a figure from our brother, the surveyor) of obtaining an accurate base line for his triangulation; that is, to produce a set of uniform paint coatings on which to work. Hand labor and the brush needs must introduce a variable due to the personal equation of the operation, be he ever so conscientious.

The result of investigations upon a great number of paint coatings where all the factors were constant, excepting this one factor of hand brushing out, has convinced the writer that until some scientifically accurate means can be developed of preparing standard paint coatings, it will be impossible to get results of precision which are comparable even with the most careful measurements on two paint coatings produced under absolutely uniform conditions excepting for this one variable. It cannot be too strongly urged that the laboratories and technical experts connected with the corporations producing scientific machine-made paint should make an effort to eliminate this variable, so that absolutely uniform paint coatings for laboratory samples can be produced from liquid paint of any given fixed composition.

In the case of the measurements and figures given as the result of the writer's investigations, the greatest care has been taken to reduce to a minimum the variable of hand brushing, and the figures derived from measurements are of value for purposes of comparison, but the data given is valuable rather as pointing the way to more precise measurements than for purposes of precision.

ELASTICITY AND STRENGTH.

In these qualities the paint coating follows in many respects the laws governing concrete. Taylor and Thompson (page 275) state that tests at the Watertown Arsenal showed the ultimate strength of concrete to be identical with the shearing strength of the stone included, which makes the resistance to shearing directly dependent on the strength of the broken rock used in the mixture. In a paint coating, the physical properties of incorporated pigments profoundly modify the qualities of the film.

Linoxin while notably elastic is weak in shearing and tensile strength, as well as in hardness or resistance to surface wear. The semi-solid linoxin between the pigment particles obviously uses the latter as supporting points and where the paint is made up on the approved concrete principle with the solid particles of three or more determinate sizes, the linoxin and the smaller particles between the largest particles or piers may be considered as flat arches supported by false work in the shape of the structural material on which the coating rests. The larger particles of pigment cannot stiffen or reinforce the qualities of the semi-solid linoxin since they have a determining influence on the total thickness of the coating and in notable instances are thicker than the oil coating itself when not modified and strengthened by smaller particles.

Raw linseed oil and boiled linseed oil, with normal percentages of thinners, spread under a flat brush to the thickness of .00135 and .00065 in. respectively; while the diameter of the larger particles of old Dutch process lead is .0030 in. or more than twice the thickness of the former and five times that of the latter. A careful study of the physical characteristics of dried linoxin with due regard to the modifications obtained by admixture of pigment particles of extreme fineness has convinced the writer that these decidedly change the physical qualities of the vehicle. They undoubtedly add immensely to its tensile strength and considerably retard the penetration of destructive agencies, both material and actinic.

The particles of intermediate sizes may simply be used to fill the primary voids or may be of a form serving to reinforce the flat arch of linoxin. Asbestine pulp, for example, no matter how finely ground, retains its needle-like form and in the paint film serves a similar purpose to the iron bars or iron netting in reinforcing concrete arches. The smallest sized particles, which are drawn usually from the group of sublimated pigments, serve in the paint film a similar purpose to that of the sand in concrete.

Each particle of pigment in a paint film without reference to size, is enveloped in linoxin. Given similar homogeneous coatings under identical conditions, elasticity will vary directly with the thickness. By direct deduction, we note that of two paint coatings equal in strength, opacity and all other qualities excepting thickness, we should chose the thinner coating.

The data on hand regarding thickness of paint coatings is confused and misleading, having apparently been based upon specific gravity and weights, and having neglected the item of shrinking on drying. In our calculation the first coat on any absorbent material must be eliminated, and it should also be remembered that the thickness of any coating will vary according to the method of application and the personal equation of the painter.

The writer has sought to determine the relative thickness of well known coatings under identical conditions of consistency, brushing, etc. Measurements made in great numbers under these conditions show that the dried second coatings compare as follows:

	Inch.
A scientific machine-made paint	.0010
American Green Seal zinc	.0006
Lithopone	.0008
Quick process and precipitated leads	.0012
Dutch process lead	.0015

Neglecting fractions and taking the machine-made paints as the standard at 100 we have the others in the following percentages:

	Per cent.
Zinc oxide paint coating	60
Lithopone	80
Scientific machine-made paint	100
Quick process white leads	120
Dutch process white lead	150

In selecting the proper thickness and most elastic coating, we must still bear in mind the necessity of filling our voids with pigment particles of three or more different sizes, so as to produce impenetrability and shearing strength, remembering also that the zinc oxide and other sublimated pigments having extremely fine particles are incorporated with the tough linoxin like the sand in concrete, and that the group of alteration products are of medium size and compare with the smaller broken rock in concrete; while the Dutch process white lead is comparable to the coarsest grout. It is logical that a properly prepared paint coating to be of the correct thickness should fall about half-way between the extremely thin coating formed with zinc alone and the excessively thick coating formed with Dutch process white lead.

ADHESIVE POWER.

The adhesion of the linoxin to the coarser group of particles as well as the underlying material is vital to the coating. If the coating parts from the surface beneath we have scaling and peeling. If the linoxin parts from the included particles of pigment we have chalking and disintegration. In the case of the well-recognized tendency of zinc to crack and scale when used alone as a pigment, we may conceive of our arch of linoxin practically without piers or points of support, zinc oxide used alone gives better results in interior work where extremes of temperature are avoided.

Three major lines of forces hold our linoxin in place—adhesion to the supporting surface, adhesion to the coarse particles of pigment and cohesion within the linoxin itself. Recurring again to our figure of a flat arch, we can represent its adhesion by a downward pointing arrow; the adhesion to the coarse particles by two arrows within the arch, pointing away from each other, while two others pointing mutually toward the center of the arch represent the force of cohesion. If by reason of an excess of coarse particles the paint coating be too thick, areas of unequal strain will occur in the arch because of too rapid surface drying and consequent destruction of the balance between adhesion and cohesion. Such excessively thick coatings break down exactly as may be expected. The linoxin pulverizes and the coating chalks. Furthermore, if the coarse particles or supports themselves be defective the laws governing the strength of the arch will again lead the physicists to predict crumbling. Thus when white lead is used alone to support the linoxin and attacks the latter chemically the piers themselves disintegrate and the arch falls.

IMPERVIOUSNESS.

For durability and protection, the strength and imperviousness of the paint film are vital factors. The protective value of a coating ceases with chalking or disintegration; even the linoxin is itself somewhat pervious. It is an office of the pigment to reduce this perviousness. The more impervious the film can be rendered without loss of strength, the slower is the process of internal oxidation and disintegration and the greater the protection of the underlying surface. A coating of linseed oil alone is not only weak, but, as Dr. Dudley has conclusively shown, it is quite pervious to moisture, and this perviousness increases rapidly with progressive oxidation.

Therefore the question of rendering a paint film impervious depends upon our success in filling voids and in protecting the linoxin of the film from the agencies of destruction. The conditions percisely parallel the service requirements for concrete. Taylor and Thompson have clearly shown that to secure imperviousness in concrete there must be freedom from voids, and that to obtain this condition, we must have at least three determining sizes in materials used, and their conclusions can be summarized, as follows:

> The largest percentage of voids occurs when the grains are all of the same size. The least voids occur when the voids between the larger particles are filled with smaller particles and when the smaller voids between the smaller particles are in turn filled with still finer particles

OPACITY OR OBSCURING POWER.

The actinic rays of light undoubtedly tend to destroy the paint film. It is of the utmost importance that the dried paint coating shall be opaque and if this quality be obtained and a proper balance of pigments provided, reasonable durability may be expected. The coating must be homogeneous. It is obvious that to obtain the best results from pigments properly mixed in accordance with physical laws, the incorporation of the pigments with the vehicle must be complete so that all portions of the resulting coating may be as near as possible of constant composition.

OPACITY—ITS MEANING AND MEASURE.

It has been the custom of the paint trade heretofore to think of the opacity or hiding power of the pigment purely from its visual or decorative side.

The pigment which best obscured the underlying surface and in the case of lighter shades, reflected back the greater portion of light received has been considered the most opaque, and doubtless, therefore, other things being equal, to possess the greater protecting power. Pigments differ in their apparent opacity in accordanec with their refractive indices. Inasmuch, however, as one of the most important functions of a pigment is to protect the underlying parts from the action of the actinic rays, it seeemed that an investigation of the various pigments with regard to their obscuring action toward these rays were well worth while. The investigations which have been as extensive as the limited time would allow, show that we must readjust our ideas regarding the opacity of the various pigments, when dealing with the question of their behavior towards the chemical rays as compared with their action with the visual. The process worked out for a comparative determination of the photometric or actinic light—excluding power of the various pigments was as follows:

Various raw materials were incorporated in the same suspending vehicle and brought as near as possible to proper consistency or viscosity, glass slides were prepared showing one, two and three coats with sharp demarcation—these glass slides were treated as photographic negatives, *i. e.*, a sensitized silver film (standard velox paper) was exposed under each to a constant illumination and the time of exposure varied until prints of uniform density were obtained from each pigment screen—the time of development and all other conditions were constant. The development as well as the exposure were timed by a stop watch. Considering the time of exposure for comparative purposes as a measure of their actinic light excluding value, the pigments group themselves as follows, as compared with American XX zinc, taken as 100 per cent:

		Per cent.
Group No. 1.	XX American zinc oxide	100
	American zinc lead	100
	Machine-made outside white	110
Group No. 2.	Sublime lead	
	G. S. Beckton white (lithopone)	67
Group No. 3.	Quick process lead	23
Group No. 4.	Old Dutch lead	17
Group No. 5.	Barium carbonate	
	Paris white (bolted)	4
	American floated barytes	
	Blanc fixe	

		Per cent.
Group No. 6.	English China clay	2
	Asbestine pulp	
	Silex	
	Gypsum	

It is interesting to note how close these photometric values compare with grouping of the pigments made with reference to fineness and also with similar groupings made with reference to their origin. Pigments which are produced by sublimation, and which are therefore extremely fine, fall into the first group of greatest actinic exclusion or actinic opaqueness. Those materials which are chemical alteration products, or natural products produced by natural alteration or decay, fall into the second group and are next in size of particle to the sublimated group. Those materials which are natural products not largely modified by natural decay and which also have the largest determining size of particle constitute the third group and have the least actinic opacity.

While the figures given are, as has been said before, valuable only for a comparison, we may expect that in the near future by the use of accurately standardized photometers, it will be possible to express photometric values in terms of a known standard unit.

EXCLUSION OF VISUAL RAYS.

The question naturally arises—"To what extent do the visual rays penetrating a paint coating correspond with the chemical?" Results expressing these values are shown in the following table, being expressed in terms of American zinc as 100 per cent. or total opacity:

TABLE OF TRANSMISSION OF VISUAL RAYS.

		Per cent.
9	American zinc lead	100
12	XX American Horsehead zinc	100
11	G. S. Beckton white	91.7
13	Quick process lead	91.7
10	Picher lead	87.5
14	Dutch process lead	87.5
3	Barium carbonate	75.0
7	Paris white, bolted	70.8

		Per cent.
1	Asbestine pulp	66.6⅔
4	Blanc fixe	58.3⅓
5	Silex	45.8⅓
8	Barytes	41.6
2	English China clay	25.0
6	Gypsum	4.16

In connection with these two tables showing the photometric values, it is interesting to compare the settling of the several pigments in water suspension. The results given in the following table show the relative suspension of the several pigments in water after standing a number of months:

TABLE OF SUSPENSION OF PIGMENTS.

	Per cent.
XX zinc	100
English China clay	69
Gypsum	46
White lead	39
Barytes	15

PAINT LEGISLATION.

By E. F. Ladd.

Few industries have developed during the past few years more rapidly than the ready-mixed paint industry. Probably no less than 70,000,000 gallons of mixed paints are now annually produced and consumed in the United States. Mixed paints are a necessity of our age; they are most convenient for use, the colors easily matched at any time, and it is not strange that the growth has been phenomenal.

I need not dwell upon the products first produced and sold as mixed paints; it is sufficient to consider what we now have to deal with. It is not strange then, with the wonderful development of the industry, and with the multitude of manufacturers now producing paints, some of whom seem to know very little of the business, or of the true principles underlying the manufacture and use of paints, if, without being under any restriction and control in such a rapid growth of the industry, that abuses should be found which will require courage, persistence, and even legislative action to correct, in order to insure proper protection to the public.

It is unfortunate that some of the mixed paints have so little of merit, but how are the public to separate the good from the bad? I am, I believe, prepared to show that about 80 per cent. of the manufacturers of paints are misrepresenting the facts to the public; they are deceiving them; misleading them, and, in not a few cases, defrauding them. This will be well proven by a study of Bulletin No. 70 of the Agricultural Experiment Station when taken in comparison with the literature furnished by the manufacturers themselves.

With competition so fierce as has been the case within the past few years it is safe to say that paint manufacturers have not, as a rule, produced a paint as good as they know to how produce, but rather that the best of them were making as good a paint as they could sell in the face of the competition practiced. Unfortunately, there are many other manufacturers producing paint as cheaply as they can, and with little regard for the wearing quality as the first consideration; paints, for example, in which 75 per cent. of the liquid portion is without any merit whatever, being chiefly water and benzine.

I would not for a moment have it understood that I believe that all the manufacturers of mixed paints resort to unfair methods; far from it; there are as honorable, high-minded, and public-spirited men among them as can be found in any calling, and I count among my acquaintances many such.

The conditions are not unlike they were in food matters when food control laws were first enacted. The standard of business was set not by the best men but by those who were shrewdest and not necessarily the most honorable. I know well too that the "almighty dollar" has so far lured many of their number from what is just and right that they resort to fraud and deceit of every kind that is applicable to the business, and in so doing they have brought discredit upon the others. Their methods must be changed or they will be forced out of business; then the honest man will be afforded an opportunity to do the very best he knows how to do in producing a superior product, and he will not be forced by unfair competition to lower his standard in order to hold his trade, not educated to recognize in paint that which possesses true merit.

It should not be forgotten, however, that there is a demand for two grades of paint; a first and a second quality. But the honest manufacturer should make both, then so label them that the public shall know the difference, and the proper use of the two classes of paints. He should not leave this to others who will produce any kind of a mixture that can be sold and to the detriment of a good paint.

CLASSES OF MATERIALS USED IN PAINTS.

It should be understood that our discussion has to do with ready-mixed paints for house painting, and not with specialties, or paints designed to be used where engineers and chemists are employed and so can safeguard the interests they represent.

This leads us to a discussion of materials used in paints, and for convenience we may divide them into three groups:

1. Basic or statutory pigments: White lead and zinc oxide.

2 Class A pigments: Sublimed lead, leaded zinc, lithopone, and zinc lead white

3. Class B pigments (erroneously so-called inert pigments): Gypsum, chalk, barytes, silica, etc.

The majority of the paint manufacturers admit that white lead and zinc white have been, for a long time, recognized as the basic constituents entering into the composition of the best grades of mixed house paints. Whether rightly or wrong, manufacturers have aided in creating this impression, and have so claimed to the public by setting forth the merits of their own product as being produced from these constituents. The working and wearing quality of these two pigments are likewise well known to the public, and form their standard of comparison for house paints. The public have, therefore, a right to know when other products have been substituted or added to the pigment employed in paint making, and to know the reason for such change.

Are the Class A pigments the equal of the old Dutch process white lead, or the best French or New Jersey zinc white? Paints containing zinc lead whites in considerable proportion, in my experience, cannot be depended on to wear well; they soon begin to wash and run. Some recent experiments with well-known paints containing zinc lead white were found to give bad results; at the end of a few months they were washing badly,—at the end of nine months they were showing considerable disintegration. The reason for this may probably be found in the fact that the lead sulphhate is not a good paint material, and in combination we should not expect it to be free wholly from the objectionable qualities. Again, it is objectionable for the further reason that the product is not of uniform composition, containing varying amounts of arsenic and antimony compounds, and zinc sulphate. Samples recently examined in my laboratory show the following range for these constituents when calculated as:

	I	II	III	IV
Arsenious oxide	.68	.47	.32	1.60
Antimony oxide	.20	.33	.20	.88
Zinc sulphate	.78	.55	1.61	.84

In other words there may be present fully three and one-half per cent. of these ingredients.

The presence of arsenic in interior house paints is certainly not more to be commended than is wall paper containing the same ingredient. It was only a few years ago that physicians and sanitarians alike compelled the discontinuance of the use of arsenic in wall paper, and caused paper containing such arsenic to be removed from the walls, having clearly demonstrated to their own satisfaction that many cases of ill health could be traced to this slow poisoning by arsenic. We cannot afford to again ignore the matter at this time. Certainly there was less arsenic in the paper than is now found in the paints containing some of the zinc lead whites. The leaded zincs of Missouri and Kansas contain from 4 to 10 per cent. of lead sulphate, and as high as one and a half per cent. of zinc sulphate. What has been said about the wearing quality of paints containing zinc lead white is equally true, in our experience, with those containing leaded zinc.

Lithopone has a place in floor paints, in some enamels, in the oil-cloth industry, and in many specialties, but its best friends have not been enthusiastic over its use in ready-mixed paints, for many of its shortcomings are well known.

This brings us then to a consideration of sublimed lead, the use of which has increased in the past few years. Its greatest use will not, however, in my judgment, be found in the highest grade of ready-mixed house paints. The difficulty of satisfactorily applying paints containing considerable portions of sublimed lead in cold weather, and even in the cooler parts of the day, are no new thing, but well understood. Other difficulties have been pointed out and considered by the writer in "Analysis of Mixed Paints, Color Pigments, and Varnish"; certainly then if what I have said be true, it cannot be claimed that the substitution of pigments of Class A for white lead and zinc white without the knowledge of the consumer would be justifiable. In other words, they are not the equal of the basic pigments so long and favorably used by the public as their standards for pure paints.

Class B pigments have cheapness as one of their chief merits and therefore an unlimited opportunity for misuse is offered, and taken advantage of. Those who are best posted do not generally claim that they are substitutes for white lead in oil, but rather that they can be used in combination with white lead within certain limits. There is, however, no fixed concensus of opinion either among paint manufacturers or their chemists as to which is best; some manufacturers condemning one and extolling the merits of another, while a competitor will contend as vigorously that the reverse is true. Some of the products employed in this group are very far from being either pure or inert. This is true of some forms of gypsum, which, when not properly dehydrated, and containing quicklime, cannot by any means be considered as inert material, for its presence produces most serious results in some paints.

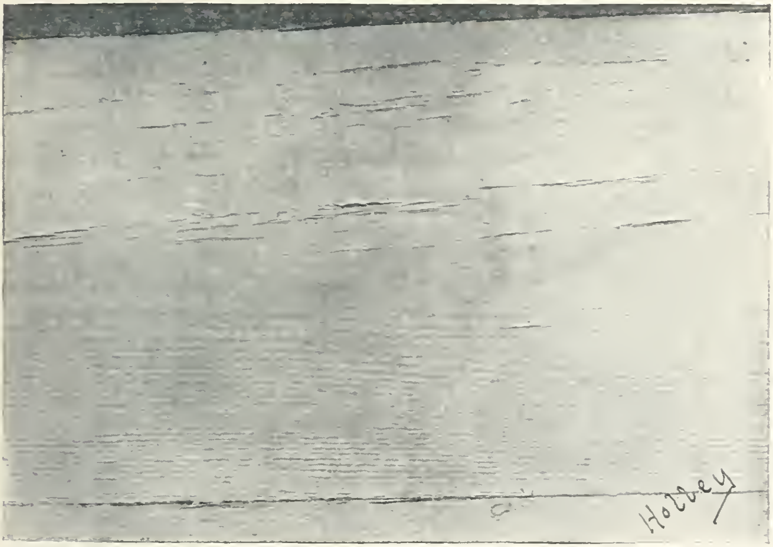

FIG. 1.—Condition of Cheap "Dope" Paint after Nine Months' Exposure. Peeling Badly.

It is to be borne in mind, however, that not a few paint manufacturers are ignorant of the chemistry of paint materials; they are in reality "mixers", according to a prescribed formula that has come into their possession, and are often as unacquainted with the science of paint manufacture as they are with its chemistry.

Even lime carbonate is not always an inert ingredient of paint, but at times is employed on account of its possibilities as a chemical agent. The necessity for its use might sometimes well raise a question regarding the character of the oil employed. Some of the paints containing rosins, alkali, emulsions, etc., have been a source of trouble, little understood by the manufacturer, because he did not always know that these products were present in his factory.

THE KIND OF A LAW.

What shall be the nature of the proposed paint law,—one that shall be fair alike to producer and consumer? Shall we have a law which recognizes no difference in value for the several paint pigments; one which places all pigments on the same basis; a law which recognizes in chalk the equal of zinc oxide, or in zinc lead white with its arsenic, antimony, zinc sulphate and soluble lead sulphate (which has its serious faults), the equal of old Dutch process lead? No honest manufacturer or painter believes that these pigments are of like value as ingredients for ready-mixed house paints. Why then should we demand that each be legalized and made of like value under the law? Perhaps because we have not looked into the future and discerned the competition that must be met, and successfully answer the claims made effective by sanction of law. The honest manufacturer knows that the basis of the best paint he has been able to produce is white lead and zinc oxide, even though he may have been able to add with advantage some proportion of other constituents. Many will differ with him regarding the proportion of pigments; none I believe will successfully assert the equal value of all pigments, or of all vehicles for paint.

If all pigments are not of like value, then we must turn to some one or two pigments which shall serve as standards of comparison when these standards have been properly tested and accepted. Is the concensus of opinion, both public and individual, to be followed? If so, then our standard of comparsion is still white lead and zinc oxide. Shall these then constitute the basis on which our law shall be built up? Can we find anything better? And why should we not have a standard for comparison in paints the same as is found for every preparation in the United States Pharmacopœia, or, the same as there are standards well recognized for commercial fertilizers? If there be added to or substituted into this combination any other pigment why should not the public be informed of the fact? Or, if water or benzine be added in place of some constituent in the vehicle, why should not the public know of this substitution?

A few have maintained that a law should be such as to exempt from labeling only those statutory paints wherein the white lead constitutes not less than 50 per cent. of the pigment; others would allow 5 per cent. of truly inert material like barytes or silica without requiring labeling.

THE NORTH DAKOTA LAW.

The legislators of North Dakota recognizing the necessity for a paint law came to the conclusion that all paint pigments were not of like value, and have so formulated their belief and expressed it as a law.

Paints composed wholly of pure linseed oil, pure carbonate of lead, oxide of zinc, turpentine, Japan drier, and pure colors, need not be labeled, while all others must be labeled so as to show their true composition. North Dakota has thereby established the standard long recognized, but in so doing they have barred no paint from the state; they only ask that you tell the truth to the public with regard to the composition of the paint,—that you place your name and address upon the package as a guarantee of your own faith in the product which you desire to sell in the state. Our experience under the North Dakota law convinces us that the principle therein enunciated is the correct one, safest alike for safeguarding the interests of the consumer and the honest manufacturer. Industries employing chemists, engineers or experts to look after their interests may well require and have special paint products for their particular purposes, but the public at large who use mixed paints for house painting demand and are entitled to legislative protection, since in no other way can their interests be properly safeguarded.

It is true that other basic or statutory pigments may be best for special purposes. Possibly a great railroad may prefer that its paint should chalk and wash, in order that the cars may appear cleaner or whiter than would be the case were paints employed that do not possess these properties. Other pigments may be far better for structural steel works, light-house, bridges, breweries, etc., but we have here to deal largely with house paints, used by those not in a position to know what is being sold often under deceptive captions.

Certainly the public will be misinformed if they follow the claims of the makers of these paints and, in the light of recent experiences, we cannot wholly blame them where they assume an attitude of doubt. My two years' experience in enforcing the North Dakota law, and in experimenting with paints, has given me less faith in the value for house paints of the pigments of Class A, than I formerly had, and unless they are very materially improved, I predict that, in the very near future, they will be less extensively employed in house paints than is the case at the present time.

THE FORM OF LABEL.

Whatever the law, it is important that a uniform labeling feature be provided for, and North Dakota has to recommend the following as affording the information most sought for, and with least likelihood of evasion. This is not intended to convey information regarding an ideal combination but rather indicates the form for a paint that should be labeled.

Contents of can. .... gal. .... lbs.

Per cent. of pigment, by weight	62
Per cent. of thinner or vehicle, by weight	38
	100

The thinner or vehicle is composed of:

	Per cent.
Linseed oil	70
Turpentine	5
Japan drier	5
Benzine	10
Water	10
	100

Composition of pigments:

	Per cent.
White lead	25
Sublimed lead	20
Zinc oxide	30
Calcium carbonate	6
Barytes	15
Color *	4

---

* The color is composed of (name of ingredients and composition, if necessary, to be given).

In mixed paints it is important that we have full measure, while in white leads and paste paints, weight will be more important. It is desirable, however, that we have shown the per cent. of pigment and vehicle, as will be readily understood by those who have made a study of the commercial features of this problem. The public understand the magnitude of any fraud better where the pigment and vehicle are separated, and where each is separately expressed in per cent. as shown above.

With regard to color,—when a pure product is used, it is sufficient to name the color pigment, but where inferior colors are employed it is necessary to have a full analysis of the color pigment so as to prevent the heavy adulteration sometimes introduced by this means.

Let me cite an instance: two paints, one required to be labeled because there had been added 10 per cent. of English cliffstone; the other not labeled because made from lead, zinc, and color. Twenty per cent. of the color was used, not more than 7 per cent. of which was real color, the balance being clay, lime, etc., not properly a constituent of the color. This paint was in reality intentionally seriously adulterated, and must needs be labeled so as to show the composition of the color pigment.

NATIONAL PAINT LEGISLATION.

What is needed to prevent fraud in paints at the present time is National legislation and this would serve as a public educator to acquaint the people with the relative merits of the several pigments now employed in paints as well as with the character of the vehicle. Such a law, with the experimental work that should be conducted in connection with its enforcement, would show the people how to use these various pigments in paints in order to secure the greatest efficiency. A national law would prove of great benefit to the honest manufacturer, who is now struggling to meet the unfair competition from the sale of the many cheap paints being made by "mixers," who have no knowledge of the paint business, and when their product has been exposed will find it necessary to go out of the business. The cheap, water emulsion paints of chalk, barytes, etc., now so largely sold by the department stores would, in some measure at least, be replaced by a better product, and the mail order houses would be unable longer to impose upon the public, for education would, in a large measure, correct many of the existing evils. With a good national law as a basis the states would then follow its general form, and there would be a minimum amount of confusion and annoyance to the manufacturer in the labeling of his paints as they go into commerce.

EXPERIMENTAL PAINT TESTS.

Before we can get on a solid and correct basis for classifying paints we must have become familiar with all the conditions under which paint is used in house painting. Having carefully studied the paint question during the past two years, North Dakota has led in this important work of paint testing.

How do paints behave on the walls of buildings, or under like conditions? To answer this question there has been planned, and in part executed, probably in North Dakota, the most extensive and comprehensive series of experiments of this nature ever undertaken in this country. Our experimental testing plant is:

First, experimental fences, aggregating 275 feet in length, 18 inches above the gound, 5 feet in height, and the whole divided into 5-foot sections. This can best be illustrated by means of the accompanying photograph.

One side of the fence is clapboarded, using two types of lumber on each section, a soft pine and Washington cedar. The opposite side of the fence is plain-boarded, using soft and hard pine; therefore, there is afforded a variety of material on which to test each paint.

The fence is most substantially constructed, the cedar posts well set in cement, the top and ends well capped and the base protected from moisture below. To each of these sections three coats of paint are applied, and three types of each paint are under experiment. These are: white, colonial yellow, and lead gray. Each section of the fence will be repainted as there is need for the same and it is proposed to continue the experiment for eight or ten years.

Two classes of experiments are now under way. We are testing first the different types of paint as found upon the market, but the more important test is with paints representing types specially prepared for this work, and presented to the College by the Paint Manufacturers' Association of the United States.

For this work they have prepared and furnished sixteen types, each in three shades, and we are indebted to the same association for financial aid for conducting the experiments. The National Lead Company have also taken a deep interest, furnishing the necessary white lead, and contributing freely to further this work. The North Dakota Agricultural College is, therefore, now in a position to conduct a most comprehensive experimental test of paints.

I have thus briefly outlined the character of these experiments now in progress at the Experiment Station. In addition, however, to the foregoing test, at least six residences are to be painted; a large mill laboratory newly constructed, and the College Armory, in part to be re-painted and in part newly painted.

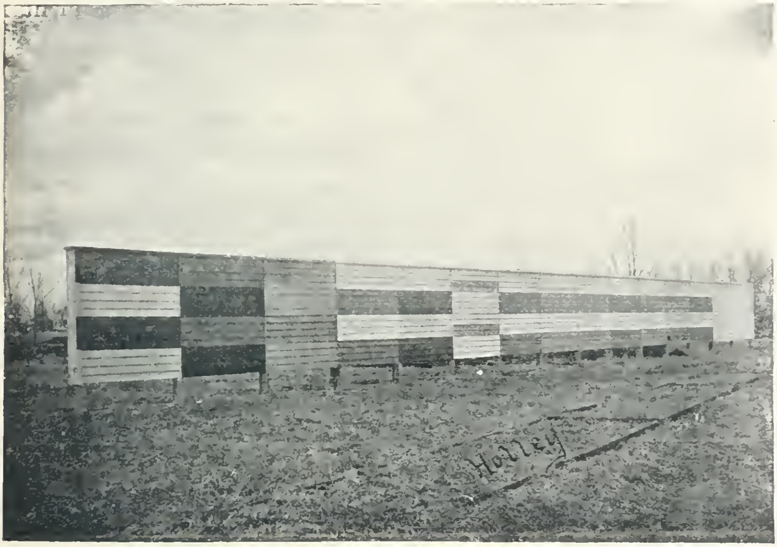

FIG. 2.—One of Five Test Fences.

On each residence eight paints are used, thus making a comparative test under identically the same conditions for the different types of paint. At the same time that these tests are being made the chemical and physical properties are fully determined and recorded, also all of the season's climatic conditions and observed facts regarding the working qualities of the paints. I might say that it is further proposed to have an experimental paint mill installed at the College for the manufacture of paint and, where possible, we shall try to have our experimental tests confirmed in a manufacturing way, by some of the large paint manufacturers.

At the College there has also been established a Division of Industrial Chemistry with special reference to the study of paints, and the training of young men in all branches of paint manufacture, analysis and testing. We thus hope to be able to train a class of men especially fitted for paint work, whether it be in the manufacturing departments or in research and experimental work.

DISCUSSION.

Mr. S. M. Evans.—In every legislative effort to safeguard the rights of the public, I believe history will bear me out in saying that legislatures generally crystallize popular traditions in the shape of laws. I believe in this particular case some traditions have been crystallized. Whether or not these traditions differ from their kind in coinciding with scientifically established facts, I shall not now discuss. But with the author at the fore in this movement the paint trade has nothing to fear, simply by reason of the fact of the experiments which he is making. These are very comprehensive and will let in the bright light of truth in due course on many points at present indeterminate. **Mr. Evans.**

I would like to point out what I believe to be the one fundamental fallacy in the author's advocacy of setting up a standard for pigments. His standard in this particular case is really a very slight protection to the rural buyer of paints, and protection to that individual is the object of the law. It is just as much an economic proposition to make a paint doped with zinc or doped with carbonate of lead, as it is to dope it with barytes or any other single pigment ingredient. It is just as cheap to make a paint composed of 95 per cent. of zinc oxide and 5 per cent. of lead, as a paint composed of 60 per cent. oxide of zinc and 40 per cent. barytes. The former is about as poor a paint as anyone can make for general purposes, and yet, under the author's standard, he would be obliged to cover it with his cloak of orthodoxy; while the latter paint composed of 60 per cent. zinc and 40 per cent. of barytes is, as everyone well knows, much superior in efficiency and yet must needs be condemned according to the standard set up in North Dakota. I just point this out as being a single glaring mistake in endeavoring to set up a standard.

Mr. William Marshall.—It seems to me that in view of the diversified opinions expressed at this meeting as to what is best, the different pigments that should be compounded together to produce best results, and in view of the fact that this Society seems to **Mr. Marshall.**

Mr. Marshall. be feeling its way to find out what is best, what combinations will prove the best for protective coatings, that any legislation at this time is premature, especially as no standard seems to have been reached. I am free from any selfish motive in this, because I am not in the paint business; but it seems to me that in view of the fact that we have not yet reached any standard, and that it will take some years of earnest and careful scientific investigation by this and other societies, and other seekers after truth, before a standard is reached, that all legislation should be postponed.

THE RECENT TESTING OF COALS USED BY THE FEDERAL GOVERNMENT IN ITS PUBLIC BUILDINGS IN WASHINGTON.

By J. A. Holmes and D. T. Randall.

There is a growing tendency in the government departments and also in the commercial world to inspect and test all materials used in large quantities. At present there are a considerable number of large consumers who systematically sample and test all the coal used in their plants. The government has done so in a few of its departments for some time past. The cost of coal for the United States Government is in the aggregate about $6,300,000 per annum. The annual expenditure of such a sum of money warrants some method of inspection to enable the several departments to secure suitable coal for a reasonable price.

This state of things has led a demand for better general information regarding the relative value of the coals available for government as well as commercial use, and it has recently been made the duty of the Technologic Branch of the Geological Survey to analyze and test the coals used by the government in addition to the general investigations conducted at the fuel-testing plant and in the field.

During the past three years trained inspectors in the employ of the Fuel-Testing Division of the Geological Survey have personally visited 159 mines in 23 states and taken two or more samples from each mine. This work was done to determine the geological features, character, and commercial value of the coal in each mining district. It was also desirable to determine what dependence might be placed on samples of coal taken in the mine as representing the coal actually delivered on the market. For this purpose two plans have been followed. In one, the sample is taken and impurities discarded in accordance with instructions to miners for separating foreign matter from the coal. This method, when checked by samples taken from coal shipped in cars under ordinary working conditions, shows that mine samples are usually considerably better than the actual delivery due to the failure of the miner to fully carry out instructions. This difference may be indicated by comparison of the ash content of the coal in the two cases. The average results show for run-of-mine coal 30 per cent. more ash in the coal delivered than in the mine sample. The other method of mine sampling follows as nearly as possible the actual methods which the miners follow regardless of what their instructions may be. By this method samples may be secured by an experienced inspector which correspond very closely with the car deliveries, but considerable time is required for observing the work of the miners in different parts of the mine, and the judgment of the inspector is depended upon to secure the result.

In both methods, the following precautions are taken by the inspector to secure a correct sample. A vertical cut is made over the face of the coal, and the cuttings are caught upon a waterproof blanket which is spread upon the floor of the mine. Impurities are rejected, in accordance either with the instructions or with the usual miners' practice, and after being crushed to ½-inch pieces or smaller, the coal is thoroughly mixed. It is then quartered down and the resulting sample is placed in a metal can holding about one quart and sealed air tight. All of this work is done in the mine where the sample is taken and as rapidly as possible to avoid loss of moisture. A full description of these methods and results may be found in the Geological Survey Bulletin No. 290 and in Professional Paper No. 48.

As intimated above, samples as usually furnished from mines are not to be depended upon as representing the coal which will be delivered. This difference is mainly due to failure of the miners to obey instructions regarding the rejection of impurities, to differences in the quality of the coal in different parts of the mine, and to the fact that different beds of coal are often mined at the same time and the output mixed. Lack of care in mining and in preparation of coal for the market explains in a great measure the variation in the amount of ash in the coal delivered from the same mine at different times. In sections of the country where coal is washed, variation in the quality may be considerable, due to the carelessness of the attendant in charge of the washery. The tendency with persons inexperienced in sampling is to select a sample much better than the average product. In many cases samples are taken by selecting a nice-looking lump, breaking it down and shipping it in a cloth sack, thus allowing the moisture to evaporate. Such a sample, of course, represents the best coal in the mine and (unintentionally in most cases) establishes a much higher value than can be commercially delivered. The mine sample if properly taken does, however, establish the general character of the coal and indicates what may be expected under favorable circumstances.

During the past winter samples of coal from several of the government buildings in Washington were secured by members of the Fuel-Testing Division and the analyses were made by the chemical laboratory conducted by this division under direction of Prof. N. W. Lord, of Ohio University. Samples were usually taken from the coal as it was being unloaded from the cars or from wagons. In the case of car deliveries it has been found that it is necessary to take small quantities from many parts of the car as it is being unloaded, in order to obtain a fair sample, for the reasons that the coal is often brought to the car from different parts of the mine, and in transit the heavier portions of the coal tend to settle to the bottom. The analyses of samples from the top and bottom of cars often show very considerable differences in the percentages of ash. In case coal is delivered to the buildings in wagons and stored in bins, it is preferred to obtain the sample by taking a small quantity from each load or at regular intervals as the wagons are being dumped into the bins. In cases of small deliveries of anthracite coal it has been found satisfactory to take samples from a number of points over the surface of the coal when it has been impossible to channel through the bin, which is preferred when practicable.

These samples vary from 100 pounds to 500 pounds, according to the amount of coal delivered. The coal is collected on shovels in such a manner as to represent the delivery as closely as possible, and is placed in closed cans, each holding about 60 pounds which are locked when filled. These samples are then sent to the laboratory crushing room in the Geological Survey building and crushed in a small rotary crusher to ⅜-in. pieces or smaller. The crushed coal is automatically divided into quarters by passing through a special sampling tube designed by the chemical division. The resulting sample is further reduced by quartering until a quart sample is secured. Precaution is taken throughout the work to prevent loss of moisture.

The following detailed analyses (Table I) are given for departments from which a number of samples were taken and represent the several sizes used. It will be noted that the variations in quality of the anthracite coal increase as the size decreases.

TABLE I.—ANALYSES REPRESENTING TOTAL COAL SAMPLED AT GOVERNMENT BUILDINGS IN WASHINGTON, 1907.

	Average Analysis.	Highest B. T. U. Analysis.	Lowest B. T. U. Analysis.	Average Analysis.	Highest B. T. U. Analysis.	Lowest B. T. U. Analysis.
	Furnace Coal, 102 Samples.			Egg Coal, 21 Samples.		
Moisture, coal as received..	4.08	4.01	4.26	4.16	3.64	4.71
Dry coal—						
Vol. comp.	2.42	2.71	2.37	3.10	3.60	1.93
Fix. carbon	87.14	88.96	84.90	86.33	87.00	86.27
Ash	10.44	8.33	12.73	10.57	9.40	11.80
	100.00	100.00	100.00	100.00	100.00	100.00
Sul. Dry coal	0.79	0.85	0.81	0.98	0.94	0.76
B.T.U. Dry coal	13,408	13,396	12,871	13,523	13,793	13,143
B.T.U. as received	12,861	13,435	12,323	12,961	13,291	12,524
	Pea Coal, 19 Samples.			Buckwheat Coal, 17 Samples.		
Moisture, coal as received...	4.81	3.40	4.58	5.09	4.60	5.32
Dry coal—						
Vol. comp.	3.02	3.07	3.50	2.42	2.87	2.41
Fix. carbon	80.94	82.16	78.75	79.53	81.56	76.32
Ash	16.04	14.77	17.75	18.05	15.57	21.27
	100.00	100.00	100.00	100.00	100.00	100.00
Sul. Dry coal	0.80	1.01	1.05	0.68	0.62	0.67
B.T.U. Dry coal	12,487	12,835	12,160	12,107	12,545	11,574
B.T.U. as received	11,886	12,399	11,603	11,485	11,968	10,959

Assuming that the value of anthracite coals for generating steam depends on the heating value of the coal, *i. e.*, that the coals may all be burned with equal efficiency, the several contracts have been calculated to determine the number of heat units in the "coal as received" for one cent; thereby indicating the relative values of the different sizes and grades of coal. See Table II.

TABLE II.—COALS USED AT GOVERNMENT BUILDINGS IN WASHINGTON.

Sampled and tested by the Technologic Branch of the Geological Survey.

Building.	Kind of coal.	No. of samples.	Per cent. of ash, dry coal basis.	B. T. U. per pound, dry coal basis.	B. T. U. per pound coal as received.	Price per ton.	B. T. U. for one cent coal as received.
State, War and Navy	Furnace, Ant.	15	10.67	13,363	12,841	$5.43	52,970
Mill's Bldg., Navy Div.	" "	5	11.14	13,277	12,750	5.43	52,600
Mill's Bldg., I. Canal Div.	" "	2	11.55	13,228	12,755	5.43	52,600
Pension Office	" "	7	10.24	13,472	12,954	5.44	53,350
Howard University	" "	3	10.53	13,348	12,960	6.00	48,380
Geological Survey	" "	3	10.48	13,430	12,959	5.44	53,360
Soldiers' Home	" "	5	10.93	13,265	12,791	5.75	49,830
Capitol, House	" "	13	8.93	13,752	13,133	5.39	54,580
Capitol, Senate	" "	16	10.75	13,363	12,796	5.48	52,300
Congressional Library	" "	14	11.11	13,219	12,709	5.44	52,330
National Museum	" "	9	9.41	13,648	13,018	5.60	52,070
Commerce and Labor Bldg.	" "	2	9.56	13,412	12,823	....	......
Coast and Geodetic Sur.	" "	3	10.88	13,262	12,741	5.75	49,640
Agriculture Bldgs.	" "	5	11.02	13,264	12,628	5.63	50,250
Post Office	Pea "	19	16.04	12,487	11,886	4.12	64,620
Land Office	Buckwheat, Ant.	15	18.05	12,107	11,485	3.02	85,190
Gov't Printing Office	Egg "	17	10.45	13,558	13,006	5.72	50,930
Freedmen's Hospital	" "	2	10.91	13,480	12,927	6.03	48,000
Bureau of Fisheries	" "	2	11.22	13,278	12,609	6.24	45,250
Fire Engine House No. 8	Stove "	2	15.78	12,675	12,291	7.00	39,330
Dist. Pumping Station	George's Creek R. O. M. Bit.	2	8.67	14,383	14,015	3.74	83,950
Gov't Hospital for Insane	" "	8	8.42	14,452	13,925	2.93	106,450

It is becoming more and more difficult to secure sufficient anthracite coal at prices which correspond favorably with the prices for bituminous coal. At the same time, there is now but little bituminous coal burned in the government buildings in Washington on account of the difficulty of preventing smoke with the present equipment, much of which is old and inefficient.

The Fuel-Testing Division of the Geological Survey is about to conduct at Norfolk a series of experiments on boiler furnaces with bituminous coal to determine a number of important factors, among which is the possibility of burning such coal without smoke in three types of furnaces, viz., one hand-fired with special fire-brick combustion chamber and automatic air admission, one mechanical stoker of the underfeed type, and one mechanical stoker of the overfeed type. All of these furnaces are to be set in relation to the boilers in the most favorable manner to secure complete combustion. The results of these experiments will be of importance not only to the government but to the entire commercial interest of the country.

[For Discussion of this paper, see page 572.]

THE PURCHASE OF COAL UNDER SPECIFICATION.

BY J. E. WOODWELL.

The recent general recognition of the importance of perfecting the equipment and method of operation of the power plant has resulted in awakening a wide interest in the problems relating to the selection, purchase and utilization of coal.

With the present knowledge of the proper methods of burning coal under the boiler, nearly all of the coals commercially obtainable may be utilized under appropriate conditions and with an equipment especially suited to the purpose, with a fair degree of efficiency, a proportionately equal return being secured from coals of lower grade. The use of many kinds of coal is influenced by the distance from the mine to a given market, or, in other words, is dependent upon transportation rates. Certain coals are not applicable by reason of anti-smoke ordinances or regulations, though such restrictions are more often apparent than real, for with proper appliances many coals now rejected may be burned without producing objectionable smoke. The coal used by the navy and merchant marine should yield a maximum heat per pound, or, what is more to the point, must give the greatest steaming radius with a minimum of storage capacity. Some coals are selected for their gas-producing qualities, freedom from sulphur, etc.; others for their coking properties.

It is within the province of the mechanical engineer to plan and install the furnace equipment in order to utilize that coal or class of coal among those available which will produce the greatest return for the net cost. When the kind of coal has been decided upon it is the duty of the purchasing agent to contract for that fuel under explicit terms which will be fair both to the producer or dealer and the consumer.

It is the purpose of this paper, first, to outline briefly some of the features of a number of specifications in general use, and second, to present the specifications which have been recently adopted by a number of departments of the government.

In the evolution of specifications for coal the oldest and most familiar requirement is that the coal of specified name shall be delivered from a given mine or district of known reputation. Without other technical conditions, such a contract neither takes account of the inevitable variations in the quality of the coal in the designated mine or group of mines, nor does it recognize the important influence of methods of mining, cleaning and sizing the coal upon its quality. Moreover, it is frequently not practicable either to secure the continuous delivery of coal from a given colliery or district throughout the life of a contract or to determine the compliance with this single condition which forms the essence of the contract. Among the other defects which the plan of purchase upon the reputation of a mine has in common with nearly all other methods not based upon a specification covering calorific value and other features, is the lack of any definite basis for the rejection of unsatisfactory coal or for inferior coal necessarily consumed.

In practice coals of the same class not only vary widely in different localities, but in the same mine, and these variations may result from differences in quality in the same or different beds, or in the methods employed in mining, cleaning and sizing the coal. In the case of anthracite coal it is often the practice to dump the output of a large number of mines producing coal of different heating values and ash contents into a central yard, from which it is shipped to dealers and consumers as a mixture. Under such conditions uniformity cannot be expected, and when coal of the desired quality is secured it is the result of chance. Even with the best intentions on the part of the operator or coal merchant, actual deliveries of coal purporting to represent the output of a given district or mine of reputation will frequently be greatly at variance with the nominal standard accepted as the basis of a contract. To cite an illustration, a considerable quantity of coal actually furnished by a reputable dealer under terms of a carefully drawn contract in which the name of the coal bed from which deliveries were to be made was specified, actually contained over forty per cent. ash as compared with an assumed ash content of six per cent., resulting in a corresponding reduction of about 50 per cent. in heating value. Moreover, the coal passed the visual inspection of officers charged with the duty of checking the weights, and of noting the presence of slate, dirt, etc. More evidence of the above character might be quoted, but enough has been said to make it evident that a contract based upon securing deliveries from a given coal bed does not assure the customer of a quality or heating value uniform with the nominal standard, or protect him against the mistakes of the contractor or his agent.

Another plan is to purchase coal on the basis of a standard and guaranteed analysis and to permit rejection if the variation from that standard exceeds certain established limits. The success of this plan depends to a considerable degree upon actually securing coal within the limits set for rejection, for in an important contract, or in the case of inadequate storage facilities requiring constant deliveries, the actual rejection of the coal might subject the purchaser to the greater loss due to delay and embarrassment in replacing the delivery, while a forced acceptance of the inferior coal without adjustment of price would in effect nullify the force of the contract.

Furthermore, in the latter case no comparative basis of settlement would be provided in the event of a necessary substitution of another coal for the one specified.

Other specifications have been drawn on the basis of assigning limiting values in the proximate analysis. A municipal specification of this class reads as follows:

> The anthracite coal must be of the best grade white ash coal, as free as possible from slate pyrites, and all other foreign matter. It must contain not more than two (2) per cent. of moisture, not over ten (10) per cent. of volatile carbon, and not over ten (10) per cent. of ash. The pea coal must be of standard size of not less than one-half (½) inch and must be free from buckweat and rice coal.
>
> The bituminous coal must be of the best grade, and free as possible from slate, pyrites, and all other foreign matter. It must contain not over one (1) per cent. of moisture, not less than fifteen (15) and not more than twenty (20) per cent. of volatile carbon, and not over seven (7) per cent. of ash, and not over one (1) per cent. of sulphur.
>
> In every case where the word "ash" is used in this specification it means to include slate, silicon, and all other incombustible solids in the coal.
>
> If an analysis shows that the shipments of coal made by any contractor do not come within these specifications as to the proportions of moisture, volatile carbon, ash or sulphur, as given in the second clause of these specifications, then when the next shipment by contractor of the same class of coal is received, an analysis will be made of a sample of the

coal at once, and if that analysis shows that the coal does not come within these specifications, that shipment will be rejected and must be removed at the contractor's expense.

Another form, quoted below, also states the limits in the proximate analysis, but provides in addition for the adjustment of payments on the basis of certain variations from the standard analysis as set forth in detail:

Quality of Coal.—The coal furnished and delivered under these specifications shall be the best grade of bituminous coal free as possible from slate, pyrites and other foreign matter. It shall contain not over three (3) per cent. of moisture, not less than fifteen (15) per cent. or more than twenty (20) per cent. of volatile carbon, not over eight (8) per cent. of ash, and not over one and one-half (1½) per cent. of sulphur, and shall be subject to analyses and tests as outlined below, to be made by a chemist named by the water board.

Method of Sampling.—Four or more large scoops of coal will be taken from each car load as it is being unloaded, so as to get a fairly equal proportion of fine and lump coal. These samples will be placed at once in a tight covered barrel in a cool place.

At the end of each month the contents of the barrel will be dumped on a clean floor, all the lumps reduced to about the size of a walnut, and thoroughly mixed and quartered. Three (3) quart preserving jars will be filled from one of the quarters into which the pile has been divided, jars will be labeled for identification, and one of them sent to the chemist for analysis. The others will be kept by the department for thirty (30) days after the chemist's report.

The chemist will analyze the sample sent him, and deliver to the water engineer a written and signed report of the result of his analysis.

Method of Analysis.—The chemist will run the contents of the final sample jar through a fine set coffee mill so as to reduce the coal to a proper condition for analysis.

The method of analysis will be that recommended by the American Chemical Society.

Payments and Adjustments.—Payments for coal furnished and delivered shall be made once each month and shall be subject to the following alterations from the contract price on account of composition.

1. If the coal contains more than seven (7) per cent. of ash, the excess percentage will be multiplied by two (2) and a percentage equal to the product will be deducted from the contractor's bill.

2. If the coal contains less than seven (7) per cent. of ash, the deficiency will be multiplied by two (2) and a percentage equal to the product will be added to the contractor's bill.

3. If the coal contains less than twenty (20) per cent. of volatile carbon a percentage equal to the deficiency will be added to the contractor's bill.

4. If the coal contains more than one (1) per cent. of moisture a percentage equal to the excess will be deducted from the contractor's bill.

5. If the coal contains less than one (1) per cent. of moisture a percentage equal to the deficiency will be added to the contractor's bill.

Rejection.—A sample will be taken from every shipment of coal and analyzed before the cars are unloaded. If the analysis shows that the coal does not come within the limits specified under the clause "Quality of Coal" as to the proportion of moisture, volatile carbon, ash, or sulphur then the shipment will be rejected and must be at once removed by the contractor at his own expense.

Such contracts are usually drawn to include one or more specific kinds or grades of coal which have been found to operate with satisfactory economy, under well-established plant conditions. With this object in view, such a specification precludes from competition many coals whose analysis approaches, if it does not regularly exceed, the limiting values.

Turning now from that class of contracts which are based entirely upon an analysis to the specifications which are based more strictly upon the thermal values of the fuel, there are many illustrations of the general recognition of the necessity of the British thermal unit rating as a contract standard.

Some of the largest central stations and private corporations have adopted as a basis of coal purchase specifications involving the thermal values of the fuel. A specification typical of this class reads as follows:

I. The company agrees to furnish and deliver to the consumer ....
....at such times and in such quantities as ordered by the consumer for consumption at said premises during the term hereof, at the consumer's option, either or all of the kinds of coal described below; said coals to average the following assays:

Kind of coal ....

Of size passing through screen having circular perforations in diameter................ ....inches ....inches ....inches

Of size passing over a screen having circular perforations in diameter................ ....inches ....inches ....inches

Per cent. of moisture in coal as delivered.................. ....

Per cent. of ash in coal as delivered................... ....

British thermal units per pound of dry coal........... ....

From following County........ ....

From following State.......... ....

Coal of the above respective descriptions and specified assays (not average assays) to be hereinafter known as the contract grade of the respective kinds.

II. The consumer agrees to purchase from the company all of the coal required for consumption at said premises during the term of this contract, except as set forth in Paragraph III below, and to pay the company for each ton of 2,000 pounds avoirdupois of coal delivered and accepted in accordance with all of the terms of this contract at the following contract rate per ton of each respective contract grade, at which rates the company will deliver the following respective numbers of British thermal units for one cent, the contract guarantee.

Kind of Coal	Contract Rate per Ton	Contract Guarantee
....	$.....Equal to......	Net B. T. U. for one cent.
....	$.....Equal to......	Net B. T. U. for one cent.
....	$.....Equal to......	Net B. T. U. for one cent.

Said net British thermal units for one cent being in each case determined as follows: Multiply the number of British thermal units per pound of dry coal by the per cent. of moisture (expressed in decimals); subtract the product so found from the number of British thermal units per pound of dry coal; multiply the remainder by 2,000 and divide this product by the contract rate per ton (expressed in cents) plus one-half of the ash percentage (expressed as cents).

III. It is provided that the consumer may purchase for consumption at said premises coal other than herein contracted for for test purposes, it being understood that the total of such coal so purchased, shall not exceed five per cent. of the total consumption during the term of this contract.

IV. It is understood that the company may deliver coal hereunder containing as high as three per cent. more ash and as high as three per cent. more moisture and as low as 500 fewer British thermal units per pound dry than specified above for contract grades.

V. Should any coal delivered hereunder contain more than the per cent. of ash or moisture or fewer than the number of British thermal units per pound dry allowed under Paragraph IV hereof, the consumer may, at its option, either accept or reject same.

VI. All coal accepted hereunder shall be paid for monthly at a price per ton determined by taking the average of the delivered values obtained from the analysis of all the samples taken during the month, said delivered value in each case being obtained as follows: Multiply the number of British thermal units delivered per pound of dry coal by the per cent. of moisture delivered (expressed in decimals); subtract the product so found from the number of British thermal units delivered per pound of dry coal; multiply the remainder by 2,000 and divide this product by the contract guarantee, from the quotient (expressed as dollars and cents) subtract one-half of the ash percentage delivered (expressed as cents).

Another form of this kind in force at this time and even more rigid in many particulars as applying to a particular kind of coal virtually specified is of especial interest as indicating a full appreciation of the financial importance of safeguarding the interests of large consumers in the effort to secure the best thermal return for the expenditure. The contract requirements are drawn with a view to procuring a definite kind of coal described as a good steam, caking, run of mine, bituminous coal, free from all dirt and excessive dust, a dry sample of which will approximate the company's standard in heat value and analysis, as follows:

Carbon	71	per cent.
Volatile matter	20	" "
Ash	9	" "
	100	" "
Sulphur	1.5	" "
B. T. U.	14,100	

The price paid by the company per ton, per lighter of coal, is based upon a table of heat values for excess or deficiency of its standard. This table places an arbitrary valuation of one cent for each 50 B. T. units excess or deficiency. (If this table is calculated in direct proportion to the price of the coal, that price would evidently be $2.82.) In addition to the corrections for heating value as determined by a Mahler Bomb calorimeter, the price paid is subject to deductions for excess of ash, volatile matter, sulphur or dust, or for a shortage in the standard lighter quantity.

Volatile matter and ash are each penalized to the extent of two cents per ton for each half of one per cent. above the standard, while excess of sulphur is penalized to the extent of six cents per ton for the first quarter of one per cent. excess and four cents per ton for each succeeding quarter of one per cent. up to 2.5 per cent., above which a deduction of twenty cents per ton is made. A further deduction of seven cents per ton is made if any lighter of coal delivered at the company's docks contains less than 700 tons.

With respect to business clauses the contract is carefully drawn, and such subjects as bond, payments, deliveries, docking, towing and demurrage, and method of sampling, testing and arbitrating test results are all explicitly covered. The amount of coal consumed by this Company, over 350,000 tons per annum, valued at about a million dollars, undoubtedly fully justifies such elaborate contract conditions.

For the average consumer, however, a much simpler form involving corrections for variation in heat units and ash only, may afford adequate protection. As a result of experience gained in the purchase and testing of coal for the government buildings located in all parts of the country combined with the broad technical knowledge of the subject gained by the Fuel Testing Division of the U. S. Geological Survey, which, under the direction of Mr. J. A. Holmes, has actively and most effectively co-operated in the matter, a broad contract form has been developed (see Appendix). After its preliminary preparation it was carefully reviewed by prominent coal dealers, engineers, private corporations and others interested in the subject, who, as a rule adjudged it to be fair and just to both parties. A meeting of the National Advisory Board for Fuels and Structural Materials appointed by the President was then called to consider the subject, and after certain modifications in form and arrangement its adoption was recommended. The specification is drawn up so as to enable users to describe the class of coal desired, which may be anthracite or bituminous, and in the latter case with such proportion of volatile matter as will include either eastern or western varieties as may be demanded. Unlike some of the specifications which have been drawn with special reference to a particular kind of coal, this form has been made sufficiently flexible to meet the varying requirements due to different locations throughout the United States and also the special needs of the local equipment.

Under this plan also, bids may be secured for a number of classes of coal procurable in a given market, and then compared with a view to selecting the one showing the highest economic value. What is actually desired is not necessarily the cheapest or the highest grade of coal *per se*, but the coal which will insure the greatest net economy in plant operation, and to attain this object it appears undesirable to establish an absolute standard for the fuel which would tend to limit the sources of supply.

It is intended to establish limits which are wide enough in any case to permit the use of the output of any mine or group of mines, provided proper care is exercised in mining and picking out slate, bone, etc. With these points in mind it is only necessary for the bidder to select coal for his proposal which will meet the description given and permit deliveries within the limits set. The bidder is also required to state the heating value of the coal as delivered in British thermal units and the percentage of ash in dry coal, with a view to the use of such statements as a basis for payment in connection with the stated price per ton. It is expected that the standard thus established by the contractors will be such as to require the least correction applying to deliveries for variations in heat units and ash, but is not expected that all deliveries will be absolutely uniform, or agree exactly with the standard. It is necessary, however, that all deliveries shall be within fixed maximum limits.

The heating value, expressed in British thermal units of coal containing approximately the same percentage of ash is essentially a direct measure of the actual value to the purchaser, and for this reason the specifications provide for an adjustment of payment in direct proportion to the variation in heat units in the coal *as received*. As the coal is weighed when delivered and the payments are based also upon the price per ton, it is necessary to determine the heating value of the coal in the condition in which it is received containing whatever moisture may be present at the time.

A further correction in payment will be made for variation of the *ash in dry coal* in order to take account of the cost of handling additional fuel and ash and its effect on the capacity of the boiler and furnace.

The system of sampling, analyzing, and testing coal delivered under the government contracts will be under the supervision of the Fuel Testing Division of the Geological Survey, in order to insure reliability and impartiality.

The application of this system will not only enable the award of a contract to be made in an equitable manner, but will also remove many of the usual causes for dispute as to the character and quality of the coal subsequently delivered, and provide a satisfactory basis for the adjustment of payments for differences in quality in favor of the party in whose interest it is due.

It is believed that the enforcement of the provisions of the specifications will operate equitably both with respect to the government and to the contractor, inasmuch as a premium is provided as well as penalty, and will guarantee adequate protection to each party. Many coal dealers have already signified their willingness to furnish coal on this basis, and have commended as well as indorsed the method.

As to the necessity for some such system, experience in applying a specification which penalizes a deficiency in heating value only, has developed an average deficiency of about 3.5 per cent., which on contracts aggregating $200,000 represents the sum of $7,000 of which not more than $1,000 can be charged for testing. Individual deliveries have in practice as mentioned before, shown as high as 47 per cent. of ash on a contract standard of about 6 per cent., and less than one half of the stipulated heating value. Under the accompanying specifications coal of this sort would be subject to rejection, or, if used, would not command a payment adequate to reimburse the contractor for the cost of cartage alone. It is also doubtful if such coal is of sufficient value to the user to repay the cost of firing and the subsequent handling of ashes.

This system of coal purchase has been established by the government for economic gain and it has been applied, therefore, with discrimination as to the size of the contract which will warrant such procedure. In general it has been justified practically on contracts exceeding $2,000 in value, though other factors than price frequently influence the choice of methods of purchase, such as limited competition, availability of coal market, etc.

Experience in the use of this method shows that frequently the correction for moisture influences the heating values of coal quite as much as variation in the ash content. In adjusting payments, therefore, on the basis of the coal as received by the consumer the brunt of the proposition is thrown upon the dealer who should make conservative allowance for probable variations in establishing the contract standard.

In certain instances bidders have submitted samples of coal with bids with a view to using the results of analysis and test as a contract guarantee. In such cases, under the stress of competition in quality, as well as price of the coal, it is to be expected that a sample would be of exceptional rather than average quality. In other instances, in which the contract liability assumed in stating heating values has developed a lack of knowledge of the performance of the fuel on the part of the bidder, the contract standard is so underrated as to result in a continuous increase in price by the payment of premiums.

In conclusion it seems proper to emphasize the importance of bringing about a better understanding between the producer and the consumer, in order that the coal operator may understand how to market his product directly or through a local dealer with reference to the intrinsic value to the user, *i. e.*, the thermal and economic values of the fuel.

The general application of this specification depends upon the co-operation between the mine operator and the dealer, so that the operator may receive the benefit from high quality and stand for the loss due to shipment of inferior coal.

The success of this method also depends in a large measure upon the knowledge possessed by the mine operator or dealer of the characteristics of the coal handled and upon the ability to control the variations in quality due to methods of mining and cleaning.

That the plan is entirely feasible when entered into by both parties with a full understanding of the conditions is evidenced by a large number of government contracts which have recently been secured upon this basis, in which the nominal price per ton does not exceed that charged for similar deliveries made without specification.

APPENDIX.

SPECIFICATION AND PROPOSAL FOR SUPPLYING COAL.

United States.....................

...................., 190..

PROPOSAL.

Sealed proposals will be received at this office until 2 o'clock p. m., ...190.., for supplying coal to the United States........ ....building at............................as follows:

....

....

....

The quantity of coal stated above is based upon the previous annual consumption, and proposals must be made upon the basis of a delivery of 10 per cent. more or less than this amount, subject to the actual requirements of the service.

Proposals must be made on this form, and include all expenses incident to the delivery and stowage of the coal, which must be delivered in such quantities, and at such times within the fiscal year ending June 30, 190 , as may be required.

Proposals must be accompanied by a deposit (certified check, when practicable, in favor of   ) amounting to 10 per cent. of the aggregate amount of the bid submitted, as a guaranty that it is bona fide. Deposits will be returned to unsuccessful bidders immediately after award has been made, but the deposit of the successful bidder will be retained until after the coal shall have been delivered, and final settlement made therefor, as security for the faithful performance of the terms of the contract, with the understanding that the whole or a part thereof may be used to liquidate the value of any deficiencies in quality or delivery that may arise under the terms of the contract.

When the amount of the contract exceeds $10,000, a bond may be executed in the sum of 25 per cent. of the contract amount, and in this case, the deposit or certified check submitted with the proposal will be returned after approval of the bond.

The bids will be opened in the presence of the bidders, their representatives, or such of them as may attend, at the time and place above specified.

In determining the award of the contract, consideration will be given to the quality of the coal offered by the bidder, as well as the price per ton, and should it appear to be to the best interests of the Government to award the contract for supplying coal at a price higher than that named in lower bid or bids received, the award will be so made.

The right to reject any or all bids and to waive defects is expressly reserved by the Government.

*DESCRIPTION OF COAL DESIRED.

Bids are desired on coal described as follows:

....
....
....
....
....
....
....
....
....
....

Coals containing more than the following percentages, based upon dry coal, will not be considered:

Ash.............................. ———per cent.
Volatile matter..................... ———per cent.
Sulphur.......................... ———per cent.
†Dust and fine coal as delivered at point of consumption.......... ———per cent.

DELIVERY.

The coal shall be delivered in such quantities and at such times as the Government may direct.

In this connection, it may be stated that all the available storage capacity of the coal bunkers will be placed at the disposal of the contractor to facilitate delivery of coal under favorable conditions.

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* NOTE.—This information will be given by the Government as may be determined by boiler and furnace equipment, operating conditions, and the local market.

† NOTE.—All coal which will pass through a $\frac{1}{8}$-inch round-hole screen.

After verbal or written notice has been given to deliver coal under this contract, a further notice may be served in writing upon the contractor to make delivery of the coal so ordered within twenty-four hours after receipt of said second notice.

Should the contractor, for any reason, fail to comply with the second request the Government will be at liberty to buy coal in the open market, and to charge against the contractor any excess in price of coal so purchased over the contract price.

SAMPLING.

Samples of the coal delivered will be taken by a representative of the Government.

In all cases where it is practicable, the coal will be sampled at the time it is being delivered to the building. In case of small deliveries, it may be necessary to take these samples from the yards or bins. The sample taken will in no case be less than the total of one hundred (100) pounds, to be selected proportionally from the lumps and fine coal, in order that it will in every respect truly represent the quantity of coal under consideration.

In order to minimize the loss in the original moisture content the gross sample will be pulverized as rapidly as possible until none of the fragments exceed $\frac{1}{2}$ inch in diameter. The fine coal will then be mixed thoroughly and divided into four equal parts. Opposite quarters will be thrown out, and the remaining portions thoroughly mixed and again quartered, throwing out opposite quarters as before. This process will be continued as rapidly as possible until the final sample is reduced to such amount that all of the final sample thus obtained will be contained in the shipping can or jar and sealed air-tight.

The sample will then be forwarded to..........................

....

If desired by the coal contractor, permission will be given to him, or his representative, to be present and witness the quartering and preparation of the final sample to be forwarded to the Government laboratories.

Immediately on receipt of the sample, it will be analyzed and tested by the Government, following the method adopted by the American Chemical Society, and using a bomb calorimeter. A copy of the result will be mailed to the contractor upon the completion thereof.

CAUSES FOR REJECTION.

A contract entered into under the terms of this specification shall not be binding if, as the result of a practical service test of reasonable duration, the coal fails to give satisfactory results due to excessive clinkering, or to a prohibitive amount of smoke.

It is understood that the coal delivered during the year will be of the same character as that specified by the contractor. It should, therefore, be supplied, as nearly as possible, from the same mine or group of mines.

Coal containing percentages of volatile matter, sulphur, and dust higher than the limits indicated on page 555, and coal containing a percentage of ash in excess of the maximum limits indicated in the following table will be subject to rejection.

In the case of coal which has been delivered and used for trial, or which has been consumed or remains on the premises at the time of the determination of its quality, payment will be made therefor at a reduced price computed under the terms of this specification.

Occasional deliveries containing ash up to the percentage indicated in the column of "Maximum limits for ash," on page 558, may be accepted. Frequent or continued failure to maintain the standard established by the contractor, however, will be considered sufficient cause for cancelation of the contract.

PRICE AND PAYMENT.*

Payment will be made on the basis of the price named in the proposal for the coal specified therein, corrected for variations in heating value and ash, as shown by analysis, above and below the standard established by contractor in this proposal. For example, if the coal contains two (2) per cent., more or less, British thermal units than the established standard, the price will be increased or decreased two (2) per cent. accordingly.

The price will also be further corrected for the percentages of ash. For all coal which by analysis contains less ash than that established in this proposal a premium of 1 cent per ton for each whole per cent. less ash will be paid. An increase in the ash content of two (2) per cent. over the standard established by contractor will be tolerated without exacting a penalty for the excess of ash. When such excess exceeds two (2) per cent. above the standard established, deductions will be made from price paid per ton in accordance with the following table:

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* NOTE.—The economic value of a fuel is affected by the actual amount of combustible matter it contains, as determined by its heating value shown in British thermal units per pound of fuel, and also by other factors, among which is its ash content. The ash content not only lowers the heating value and decreases the capacity of the furnace, but also materially increases the cost of handling the coal, the labor of firing, and the cost of the removal of ashes, etc.

Ash as established in proposal.	No deduction for limits below.	Cents per ton to be deducted.							Maximum limits for ash.
		2	4	7	12	18	25	35	
		Percentages of ash in dry coal.							
5 per cent.	7	7– 8	8– 9	9–10	10–11	11–12	12–13	13–14	12
6 "	8	8– 9	9–10	10–11	11–12	12–13	13–14	14–15	13
7 "	9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	14
8 "	10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	14
9 "	11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	15
10 "	12	12–13	13–14	14–15	15–16	16–17	17–18	....	16
11 "	13	13–14	14–15	15–16	16–17	17–18	18–19	....	16
12 "	14	14–15	15–16	16–17	17–18	18–19	19–20	....	17
13 "	15	15–16	16–17	17–18	18–19	19–20	20–21	....	18
14 "	16	16–17	17–18	18–19	19–20	20–21	21–22	....	19
15 "	17	17–18	18–19	19–20	20–21	21–22	....	....	19
16 "	18	18–19	19–20	20–21	21–22	22–23	....	....	20
17 "	19	19–20	20–21	21–22	22–23	....	....	....	21
18 "	20	20–21	21–22	22–23	....	....	....	....	22

Proposals to receive consideration must be submitted upon this form and contain all of the information requested.

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.................., 190..

The undersigned hereby agree to furnish to the U. S............... building at........................, the coal described, in tons of 2,240 pounds each and in quantity, 10 per cent. more or less than that stated on page 554, as may be required during the fiscal year ending June 30, 190 , in strict accordance with this specification; the coal to be delivered in such quantities and at such times as the Government may direct.

Price per ton (2,240 pounds).................. $..................
Commercial name of the coal..
Name of the mine or mines..
Location of the mine or mines..
Name or other designation of the coal bed or vein....................
Size (indicate information which will apply)—
Unsized............Lump............... Run of mine ......
Screened, through....inch and over....inch {Round, Square} openings. Bar screen.

Data to establish a basis for payment:

British thermal units in coal as delivered ....
Ash in dry coal (method of American Chemical Society).....per cent.

It is important that the above information does not establish a higher standard than can be actually maintained under the terms of the contract; and in this connection it should be noted that the small samples taken from the mine are invariably of higher quality than the coal actually delivered therefrom. It is evident, therefore, that it will be to the best interests of the contractor to furnish a correct description with average values of the coal offered, as a failure to maintain the standard established by contractor will result in deductions from the contract price, and may cause a cancelation of the contract, while deliveries of a coal of higher grade than quoted will be paid for at an increased price.

Signature:.....................
Address:................

Name of corporation,..
Name of president,..
Name of secretary,..
Under what law (state) corporation is organized:......................

[For Discussion of this paper, see page 572.]

METHODS OF TESTING COAL.

By S. S. Voorhees.

The paper on "Purchase of Coal under Specification" has shown what has and is being done by the U. S. Treasury Department in supplying coal to the buildings under the control of this department. During the present fiscal year (1906–07) deliveries of coal have been systematically tested from twenty-four buildings situated in sixteen cities in all parts of the United States. In all between 400 and 500 samples of coal have been examined. The contract samples, together with results of deliveries made at each building, are tabulated and form a part of this paper.

The integrity of any method of testing coal depends on a satisfactory scheme to secure a representative sample. Unlike power plants and other large consumers of coal, public buildings are usually so situated as not to permit deliveries by belt conveyors or such automatic devices. The coal bins are usually under the pavement with limited headroom so as to require wagon deliveries through coal chutes. The method requires that a sheet steel bucket of 1 cu. ft. capacity be filled with fine and lump coal from every five wagon loads as it is being delivered. These samples of about 60 pounds are placed in large galvanized iron receptacles of about 800 pounds capacity with tightly fitting lids. This gross sample will represent two weeks or one month deliveries as the consumption requires. The gross sample is spread out on a clean cement floor, the large lumps broken down, thoroughly mixed by shovel and rapidly quartered, opposite quarters rejected and the process repeated, breaking down lumps, till final sample of about two pounds is obtained. This sample is forwarded to the laboratory in quart milk jars, sealed air tight. By this process a truly representative sample is obtained and moisture losses are minimized.

On receipt at the laboratory the contents of jar are put through an enclosed hand power coffee mill and broken down to the size of fine shot. A sample is taken for moisture determination and bottled air tight. A final sample of about 30 grams is obtained in usual manner of quartering, and finely ground in agate mortar. This sample is used for proximate analysis and calorific determinations.

The proximate analysis of coal is more or less arbitrary in character and results have not been comparable. On account of this lack of unity in method of analysis the American Chemical Society in 1898 appointed a committee to standardize methods of coal analysis. This committee gave a preliminary report in April, 1898, and a final report in December, 1899, which appears in the journal of that Society. The method recommended is well known to chemists engaged in this line of work and needs no further comment. Special precautions were recommended by the committee to prevent moisture losses.

Coal from each general locality and class seems to have a normal moisture content as it is found in the mine, and this amount is more or less constant. The per cent. of water varies from 1 per cent. in the eastern bituminous coal to 40 in the western lignites. It was further found that dry or dried coals were very hydroscopic and took up water rapidly from moist air. This water is so firmly held in the coal that it is not apparent, and only a portion passes off when the lump coal is air dried. In the former method of preparation of sample for analysis, when no especial precautions were taken to prevent loss of moisture, variable and often large amounts of water were lost during the process of grinding. Consequently the actual determination of moisture in final sample was usually low for the mine sample, though it might be high under certain atmospheric conditions. These points have been abundantly confirmed by the very exhaustive work of the Geological Survey both at Washington and in the laboratories of the Fuel Testing Plant at St. Louis and Columbus under Prof. Lord, and by other investigators.

As used in this specification, the ash is calculated to *dry coal* and the heat units are calculated to *coal as delivered* from the two moisture determinations as outlined above,

Calorific power or heat value is the amount of heat developed by the combination of a definite amount of fuel with oxygen. It is expressed by the unit calorie or British thermal unit. The calorie is the amount of heat absorbed by unit weight of water when its temperature is increased 1 degree centigrade. The unit weight of water is either 1 gram or 1,000 grams. The B. T. U. is the amount of heat absorbed by one unit (usually 1 pound) when its temperature is increased one degree Fahrenheit. As a unit weight of the fuel develops a fixed number of calories with the same unit weight of water it is immaterial what unit weight of fuel and water is taken. To convert calories to British thermal units it is only necessary to multiply by the factor 1.8, which is the ratio between the Centigrade and Fahrenheit scale.

There are two general methods of determining the calorific power of fuel, which may be called the direct and the indirect method. The indirect determination is obtained by calculating from the results of ultimate chemical analysis, based on well-established values of the heat of combustion when carbon, hydrogen and sulphur are burnt to their final products of carbonic acid, water and sulphuric acid. The sum of these values, less that part of the hydrogen which might combine with the oxygen in the fuel to form water, gives the calorific value. In general, however, this calculated value agrees with direct determination of heat units by the bomb calorimeter on anthracite coals and cokes to within one per cent. On bituminous coals, high in complex hydrocarbons, the agreement is not so close. This is due to inaccuracies in analysis of these complex hydrocarbons and resulting variations in the assigned value for heat of combustion. Lord and Haas have found from working on some forty-four samples of Pennsylvania and Ohio bituminous coals that this variation amounts to from a minus 2 to a plus 1.8 per cent.

The direct method of determining heat values is based on actual measurement of the heat produced by combustion. With proper design of apparatus and with proper precautions and corrections this method gives the most accurate results possible to attain. It is used in fact as a standard to determine the accuracy of all other methods.

The two general types of calorimeters are those in which the pressure remains constant or the volume remains constant. In the first type with constant pressure the charge is ignited by means, usually, of a fuse in an atmosphere of oxygen, or is mixed with a substance which yields oxygen; the products of combustion pass through and give up their heat to a known weight of water which gives the measure of the heat developed. Many inaccuracies result from heat losses due to lack of proper insulation and incomplete combustion, etc.

The constant volume or bomb calorimeter is the instrument which is now accepted as standard in determining heat values. In its original form as designed by Berthelot, it consists of a shell made of high carbon steel capable of withstanding a pressure of 300 atmospheres. The shell is lined with platinum to prevent corrosion from resulting gases. The bomb is surrounded by a known weight of water. The vessel containing this water is insulated by an air space. The air space is surrounded by a jacket of water which is supposed to be at room temperature, and this outside water jacket is further protected by an insulating felt or hair covering to minimize local variation in outside temperatures. The determination is made in a room free from drafts or direct sunlight and of uniform temperature throughout. The temperature measurements are made by a special thermometer very sensitive and accurate graduated to $\frac{1}{100}$° C. The readings are made through a telescope at some distance form the calorimeter so as to avoid errors due to radiation of heat from the body.

The instrument may be standardized by several methods: First, the combustion of known weights of a pure substance of accurately known composition and heat value such as sugar, or naphthalene; second, by calculation from the specific heat of the known weights of the metals, used in the construction of the bomb; and third, by adding a definite amount of warm water at known temperature to a definite amount of water at some known lower temperature in the calorimeter and noting the resulting temperature. From this data the actual heat equivalent can be calculated. The determination by each method is duplicated until satisfactory averages are obtained and a mean of these averages insures a figure for the water equivalent of the apparatus which is very near the truth. The calorimeter used by the Treasury Department is a modification of Berthelot bomb designed by H. J. Williams of Boston, and is especially adapted for combustion of coal. The water equivalent of this particular bomb is 474 grams; 1,500 grams of water are used. With a normal coal the actual rise in temperature due to combustion of 1 gram is about 4° C.

The usual method of compressing powdered sample into tablet is followed with bituminous coals. With some of the western lignites, high in ash, combustion will not take place if too great pressure is used in making tablet. Anthracite coal cannot be compressed into a tablet, and can be fired by addition of about .250 gram of a bituminous coal of known heating value.

The oxygen is supplied from two cylinders containing 100 gallons under about 1,000 pounds pressure. When the pressure falls below 300 pounds, the amount required for a combustion, the bomb is filled from the low-pressure cylinder and the pressure brought up to the required amount from the high-pressure cylinder. In this way all the oxygen can be used from each cylinder. Failures to fire are rare and combustion is complete if proper precautions are followed. Determinations are always made in duplicate and almost invariably agree to within 50 B. T. U., or about one-third of one per cent. The practice of reporting heat values to the decimal or even to the final whole number assumes an extreme accuracy which the determination does not warrant. It would be far better and would not affect values, if the B. T. U. were reported to the nearest ten.

In the following tables the contract standard was established by test of sample submitted by bidder. In a number of cases this sample was hand picked and gave too high a value for the carload or even the mine sample. When possible this standard was reduced to a normal delivery value, if it was evident that the standard was too high and the contractor showed a desire to live up to the specification.

The specifications under which these coals were tested were based on dry coal and did not take into consideration *moisture* in coal as delivered. On this account no especial precautions were taken to prevent moisture losses during preparation of sample. The figures given for moisture in coal as delivered are probably 1 to 2 per cent. low.

[For Discussion of this paper, see page 572.]

TABLES SHOWING APPROXIMATE ANALYSES AND CALORIFIC VALUES OF COALS DELIVERED TO UNITED STATES GOVERNMENT BUILDINGS DURING THE FISCAL YEAR ENDING JUNE 30, 1907.

Anthracite—Screenings.

Furnished to Public Building, New York City.

Coal as received.	Contract standard.	Maximum. January.	Minimum. March.	Average of 4 deliveries.
Moisture	1.86	2.65	3.29	3.26
Vol. hydrocarbons	5.99	17.71	3.91	10.34
Fixed carbon	81.03	69.60	79.88	74.83
Ash	11.12	10.04	12.92	11.57
	100.00%	100.00%	100.00%	100.00%
B. T. U.	12,812	13,437	12,673	13,050

Furnished to Public Building, Boston, Mass.

Coal as received.	Contract standard.	Maximum. November.	Minimum. February.	Average of 9 deliveries.
Moisture	3.33	4.05	3.80	3.65
Vol. hydrocarbons	6.85	6.20	7.12	7.16
Fixed carbon	78.57	80.10	74.97	77.65
Ash	11.25	9.65	14.11	11.54
	100.00%	100.00%	100.00%	100.00%
B. T. U.	12,711	13,198	12,182	12,668

Anthracite—No. 2 Buckwheat.

Furnished to Public Building, New York City.

Coal as received.	Contract standard.	Maximum. March.	Minimum. September.	Average of 7 deliveries.
Moisture	4.25	4.20	3.87	3.69
Vol. hydrocarbons	6.23	3.82	7.06	7.33
Fixed carbon	77.85	76.23	68.02	71.29
Ash	11.67	15.75	21.05	17.69
	100.00%	100.00%	100.00%	100.00%
B. T. U.	12,513	11,932	11,299	11,543

Furnished to Public Building, Brooklyn, New York.

Coal as received.	Contract standard.	Maximum. December.	Minimum.	Average of 10 deliveries.
Moisture	4.25	2.93	5.35	3.78
Vol. hydrocarbons	6.23	7.02	5.15	7.03
Fixed carbon	77.85	72.05	60.35	73.45
Ash	11.67	18.00	29.15	15.74
	100.00%	100.00%	100.00%	100.00%
B. T. U.	12,514	12,069	9,887	11,725

Bituminous—Big Vein, Georges Creek, Md.

Furnished to Public Building, Baltimore, Md.

Coal as received.	Contract standard.	Maximum. February.	Minimum. March.	Average of 10 deliveries.
Moisture	0.99	0.38	1.02	0.86
Vol. hydrocarbons	22.12	17.27	14.48	17.16
Fixed carbon	72.79	75.15	74.95	73.61
Ash	4.10	7.20	9.55	8.37
	100.00%	100.00%	100.00%	100.00%
B. T. U.	15,061	14,575	14,098	14,368

Bituminous—Pocahontas and New River Districts, West Virginia, and Georges Creek District, Maryland.

Furnished to Public Building, Boston, Mass.

Coal as received.	Contract standard.	Maximum. March.	Minimum. September.	Average of 9 deliveries.
Moisture	0.55	0.85	1.40	1.18
Vol. hydrocarbons	19.05	16.62	18.22	18.44
Fixed carbon	77.47	78.23	71.86	74.33
Ash	2.93	4.30	8.52	6.05
	100.00%	100.00%	100.00%	100.00%
B. T. U.	15,113	15,039	14,318	14,748

Bituminous—Illinois Washed Nut, Nos. 1 and 2 mixed.

Furnished to Public Building, Chicago, Ill.

Coal as received.	Contract standard.	Maximum.	Minimum.	Average of 7 deliveries.
Moisture	7.45	6.70	11.18	8.23
Vol. hydrocarbons	41.38	40.90	36.34	38.36
Fixed carbon	40.12	39.94	41.30	41.16
Ash	11.05	12.46	11.18	12.25
	100.00%	100.00%	100.00%	100.00%
B. T. U.	11,850	12,091	11,388	11,690

Bituminous—Illinois Washed Nut, Nos. 1 and 2 mixed.

Furnished to Public Building, Chicago, Ill.

Coal as received.	Contract standard.	Maximum. September.	Minimum. January.	Average of 18 deliveries.
Moisture	11.43	10.60	8.63	10.03
Vol. hydrocarbons	35.84	38.80	34.56	36.40
Fixed carbon	43.78	45.32	35.40	42.68
Ash	8.95	5.28	21.41	10.89
	100.00%	100.00%	100.00%	100.00%
B. T. U.	11,421	12,213	10,281	11,477

Bituminous—Screened Lump, New River, West Virginia District, smokeless.

Furnished to Public Building, Cincinnati, Ohio.

Coal as received.	Contract standard.	Maximum. October.	Minimum. July.	Average of 12 deliveries.
Moisture	0.72	0.72	0.57	0.81
Vol. hydrocarbons	23.01	22.28	22.95	22.12
Fixed carbon	74.90	72.85	71.68	71.70
Ash	1.37	4.15	4.80	5.37
	100.00%	100.00%	100.00%	100.00%
B. T. U.	15,581	15,075	14,555	14,798

Bituminous—New River and Pocahontas, Mine Run, West Virginia District.

Furnished to Public Building, Detroit, Mich.

Coal as received.	Contract standard.	Maximum.	Minimum.	Average of 4 deliveries.
Moisture	0.90	0.95	0.90	1.06
Vol. hydrocarbons	20.83	22.37	24.20	22.42
Fixed carbon	71.60	72.02	63.95	69.39
Ash	6.67	4.66	10.95	7.13
	100.00%	100.00%	100.00%	100.00%
B. T. U.	14,533	15,027	13,867	14,504

Bituminous—Cascade Company, Montana District.

Furnished to Public Building, Helena, Montana.

Coal as received.	Contract standard.	Maximum. February.	Minimum.	Average of 6 deliveries.
Moisture	3.01	3.75	2.83	3.65
Vol. hydrocarbons	36.61	33.05	29.19	32.88
Fixed carbon	53.47	56.55	46.73	52.62
Ash	6.91	6.65	21.25	10.85
	100.00%	100.00%	100.00%	100.00%
B. T. U.	12,676	12,969	10,711	12,170

Bituminous—Screened Lump, Pittsburg District, Kansas

Furnished to Public Building, Kansas City, Mo.

Coal as received.	Contract standard.	Maximum. November.	Minimum. July.	Average of 11 deliveries.
Moisture	3.55	2.07	3.20	3.03
Vol. hydrocarbons	36.75	35.68	34.67	
Fixed carbon	52.66	53.70	47.16	52.27
Ash	7.04	8.55	14.97	9.91
	100.00%	100.00%	100.00%	100.00%
B. T. U.	13,553	13,626	12,161	13,123

Bituminous—St. Charles District, Kentucky.

Furnished to Public Building, Louisville, Ky.

Coal as received.	Contract standard.	Maximum. September.	Minimum. March.	Average of 9 deliveries.
Moisture	3.58	1.53	6.30	5.43
Vol. hydrocarbons	40.88	40.32	33.97	37.17
Fixed carbon	47.33	48.16	47.73	46.44
Ash	8.21	9.99	12.00	10.96
	100.00%	100.00%	100.00%	100.00%
B. T. U.	12,450	12,652	11,483	12,115

Bituminous—Youghiogheny District, Pennsylvania Screenings.

Furnished to Public Building, Milwaukee, Wis.

Coal as received.	Contract standard.	Maximum. December.	Minimum. January.	Average of 6 deliveries.
Moisture	1.01	1.45	3.10	1.66
Vol. hydrocarbons	32.40	32.75	33.19	31.98
Fixed carbon	56.30	56.85	51.50	55.58
Ash	10.29	8.95	12.21	10.78
	100.00%	100.00%	100.00%	100.00%
B. T. U.	13,393	13,789	12,813	13,260

Bituminous—Centre County District, Pennsylvania.

Furnished to Public Building, New York City.

Coal as received.	Contract standard.	Maximum. March.	Minimum. January.	Average of 9 deliveries.
Moisture	0.55	0.90	2.00	1.32
Vol. hydrocarbons	23.03	19.85	16.90	20.06
Fixed carbon	71.64	73.25	70.91	70.59
Ash	4.78	6.00	10.19	8.03
	100.00%	100.00%	100.00%	100.00%
B. T. U.	14,969	14,763	13,671	14,256

Bituminous—Centre County District, Pennsylvania.

Furnished to Public Building, New York City.

Coal as received.	Contract standard.	Maximum. November.	Minimum. July.	Average of 10 deliveries.
Moisture	0.55	0.74	1.13	0.93
Vol. hydrocarbons	23.03	21.86	13.58	20.67
Fixed carbon	71.64	70.70	39.06	66.82
Ash	4.78	6.70	46.23	11.58
	100.00%	100.00%	100.00%	100.00%
B. T. U.	14,969	14,748	7,685	13,782

Bituminous—Warrior Basin, Alabama.

Furnished to Public Building, New Orleans, La.

Coal as received.	Contract standard.	Maximum. November.	Minimum. January.	Average of 9 deliveries.
Moisture	0.65	0.96	1.13	0.97
Vol. hydrocarbons	31.40	30.29	28.63	29.27
Fixed carbon	64.12	62.92	60.52	61.66
Ash	3.83	5.83	9.72	8.10
	100.00%	100.00%	100.00%	100.00%
B. T. U.	14,788	14,631	13,878	14,197

Bituminous—Pittsburg District, Kansas.

Furnished to Public Building, Omaha, Neb.

Coal as received.	Contract standard.	Mine sample taken by Geological Survey to establish new standard.	Maximum. September.	Minimum. October.	Average of 5 deliveries.
Moisture	2.41	2.45	2.85	2.65	4.17
Vol. hydrocarbons	38.27	34.15	35.15	28.64	31.69
Fixed carbon	54.40	52.60	50.90	42.59	47.87
Ash	4.92	10.80	11.10	26.12	16.27
	100.00%	100.00%	100.00%	100.00%	100.00%
B. T. U.	14,159	13,260	13,034	10,628	12,185

Bituminous—Centre County District, Pennsylvania.

Furnished to Public Building, Philadelphia, Pa.

Coal as received.	Contract standard.	Maximum. December.	Minimum. August.	Average of 9 deliveries.
Moisture	0.54	0.70	0.65	0.71
Vol. hydrocarbons	22.66	22.80	21.80	21.96
Fixed carbon	69.20	69.80	65.70	68.94
Ash	7.60	6.70	11.85	8.39
	100.00%	100.00%	100.00%	100.00%
B. T. U.	14,616	14,820	13,826	14,386

Bituminous—B. B. Lump, Illinois Coal, Illinois.

Furnished to Public Building, St. Louis, Mo.

Coal as received.	Contract standard.	Maximum. September.	Minimum. December.	Average of 10 deliveries.
Moisture	7.74	8.60	5.90	7.40
Vol. hydrocarbons	42.97	40.15	35.28	35.17
Fixed carbon	41.41	39.55	36.47	41.85
Ash	7.88	11.70	22.35	15.58
	100.00%	100.00%	100.00%	100.00%
B. T. U.	12,087	11,495	10,472	11,092

Bituminous—New River District, West Virginia.

Furnished to Public Building, Washington, D. C.

Coal as received.	Contract standard.	Composite mine sample, taken by Geological Survey.	Maximum.	Minimum.	Average of 15 deliveries.
Moisture	0.73	1.17	0.55	0.87	0.90
Vol. hydrocarbons	21.08	22.23	20.33	19.08	19.70
Fixed carbon	76.13	71.56	74.62	70.65	72.62
Ash	2.06	5.04	4.50	9.40	6.78
	100.00%	100.00%	100.00%	100.00%	100.00%
B. T. U.	15,471	14,934	15,062	14,155	14,602

DISCUSSION.*

The President.

THE PRESIDENT.—I had the pleasure of being associated to some little extent in the work that has been detailed by those who have preceded on this matter of coal specification, and my own judgment in the matter is that the report presented here, embodies the best coal specifications that I have yet seen.

Mr. Wickhorst.

MR. M. H. WICKHORST.—I should like to ask Mr. Randall, what the difference in moisture is of bituminous coal as sampled at the mine, and as delivered.

Mr. Randall.

MR. D. T. RANDALL.—That is so entirely dependent upon weather conditions that the ratio is not fixed. I might say that not nearly as much moisture is gained from rain as is ordinarily supposed. If the amount of rain that can get into a carload of coal from an inch of rain-fall be computed, it will be found to be a very small percentage in weight—not more than one per cent.

Mr. Little.

MR. A. D. LITTLE.—What is the general attitude of the coal companies with reference to selling coal on specification, are they disposed to do it if they can possibly avoid it, and what steps are necessary to make them take it up?

Mr. Woodwell.

MR. J. E. WOODWELL.—In starting any new movement of this kind we must expect some opposition, or at least failure to understand or appreciate the exact situation of the consumer and his demands for a rigid specification of this kind. In regard to bituminuos coal, I think it is fair to say we have generally very little difficulty in securing competition, not only in regular bids, but on this kind of contract form. The case, however, is somewhat different with anthracite. For some reason, either because it is controlled by fewer men, or for some other cause which may be more or less a commercial one, there seems to be a failure to appreciate the relation of thermal value to price, and the anthracite dealer seems to be better acquainted with ash than he is with the thermal unit. In fact, one of our anthracite friends denies that there are *any* thermal units in his coal. We have taken bids, I might say, in the Treasury Department, for the coal supply of our public buildings throughout the country, but so far, as already stated, we have only made an effort to place large contracts on this basis; so that it has been applied to about thirty buildings this fiscal year. In a number of these cases we have placed successful contracts with first-class heating guarantees. In certain cases the guarantees are either a little high as to quality fixed, or a little low. But I for one am willing to see contractors receive a premium at first in some cases, and I am willing to see them penalized as well. We must give and take a little in getting this system applied. **Mr. Woodwell.**

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* This Discussion covers the following papers: The Recent Testing of Coals Used by the Federal Government in its Public Buildings. By J. A. Holmes and D. T. Randall. The Purchase of Coal Under Specifications. By J. E. Woodwell. Methods of Testing Coal. By S. S. Voorhees.

THE PRESIDENT.—Some years ago, in discussing a very important matter with the producers, one of the heads of a large manufacturing establishment said he didn't see any use talking over the quality of material; he could sell all he could make anyway. I fancy that is really about the way with the anthracite coal producers. **The President.**

MR. JOHN A. CAPP.—In listening to these papers it occurred to me there are two points that might be spoken of. First, cannot we delude ourselves a little in placing a rather fictitious value on the thermal value of coal? We are largely in the hands of the man who fires that coal under the boiler, and does practical experience show that he fires less coal with 14,000 to 15,000 thermal units, than coal with only 13,000 or less thermal units? Is the coal bill any smaller, and the amount of coal consumed less, especially if automatic stokers are used? **Mr. Capp.**

The second point is with respect to the sulphur in the coal. We burn a great deal of coal in the establishment with which I am connected, and every now and then there come complaints from the power station that the grate-bars are burning out too rapidly, and that there is too great corrosion of the tubes. Sulphur is usually found to be the cause. Is there enough restriction placed on the sulphur content of the coal?

As to the last question asked, with respect to the willingness of coal dealers to sell under these specifications, my experience is that they refuse to be bound with respect to thermal units or

Mr. Capp. anything else. Some I think have not had an analysis made of the coal they sell in several years. With us the whole matter came down to the point where we had to buy what we could get. While it is well to have a specification, should we not cover those things especially which are really harmful, and be a little easy with respect to things of academic value?

Mr. Randall. MR. RANDALL.—I can say from the results of some four hundred or more boiler tests that the Geological Survey has conducted, that we believe that the British thermal units are an index of the value of coal; that, given a coal of the same general characteristics, the value of the coal is proportionate to the British thermal units in it. It is not necessarily true that a coal widely different in character from another coal is strictly comparable on the British thermal unit basis. You will notice that there is a provision in the specification for limiting the different elements of volatile matter, sulphur, etc., and those limits must be fixed in accordance with the coal that is available in the locality from which you buy it. You might have to buy coal with five per cent. sulphur in it from one locality, and might very easily get coal with less than one per cent. sulphur in other localities. You cannot therefore specify a fixed percentage. If there is any one thing that we think the analysis of coal means, it is that the British thermal unit is comparable with the proportion of water in the coal.

Mr. Capp. MR. CAPP.—I don't think the last speaker has caught the point I wished to make. Nearly all these specifications, and I have been studying a good many of them, include a sliding scale of actual prices to be paid. There is a base-price quoted for coal to a certain determined standard, a premium to be paid when coal exceeds the base value and a penalty to be deducted in case the coal does not come up to the established standard. Now it occurs to me that we may be paying unnecessarily when we pay a premium. Of course, it is obvious that the thermal value of the coal, other things being equal, determines its value as a fuel. But to the actual consumer of coal, when that consumer has not the very best facilities, this value may be misleading as a basis of estimate of the worth of the coal to him, because his stoker will not recognize the coal of high thermal value as any different from that of low thermal value, and will crowd just as much of the former into the fire as of the latter. When a premium is paid for high thermal value, full benefit will not be obtained unless less coal is used to accomplish a given object, and this is not practical with the average coal consumer. Hence it seems to me better from the standpoint of the consumer that his specifications provide a minimum thermal value to be determined by local conditions, and that they rigidly limit the amount of sulphur and ash, and define the character of ash so that it shall not be a fusible ash which will tend to clinkering. This affords full protection against inferior coal, and does not impose the payment of a premium which may actually be to the purchaser an expenditure equivalent to a penalty for an unnecessarily scientific specification. Mr. Capp.

MR. S. S. VOORHEES.—The limiting value for sulphur would depend on the locality where the coal is mined. In the western fields, Ohio and Indiana, five per cent. is normal, and it would be very false economy to ship eastern coal with less than one per cent. of sulphur there. Some arrangement must be made to prevent if possible the effect of sulphur on the grate bars. Mr. Voorhees.

THE PRESIDENT.—It occurs to me that two points are mixed here. If I buy something from a man the transaction, as far as he is concerned, is ended when I have got certain value and have paid the price for it. If I turn around and throw what I have bought in the ditch he is not responsible. If I use bad fuel or buy bad fuel and suffer loss from it, that is my affair; the specications are not called in question. The President.

MR. LITTLE.—The difficulty which we are confronted with in Boston is that the coal companies absolutely decline to consider contracts on specification. I have talked with the managers of several large companies there who say that when an order comes in to which a specification is attached, they simply throw that order in the waste-basket. I should like to have some light as to the best way of meeting this particular difficulty. Mr. Little.

MR. J. A. KINKEAD.—I had some experience with coal companies along this line, and some of them said that they did not care to work to a proposition of that kind because they were not familiar with it. It might be better, but they had not been up against it and did not propose to until they found out something about it. Others who had tried it were perfectly willing and others said that they had no possible way of determining the thermal units in it, and it cost them as much for one kind as the Mr. Kinkead.

Mr. Kinkead. other and they could not afford to lose any money on it. They did not know whether they would come out ahead, and refused to work to it. And then a third man said, "If you don't like our coal the way we sell it you can go somewhere else."

Mr. Woodwell. MR. WOODWELL.—In reply to Mr. Kinkead's little trouble, I should like to state, that the Government has just made a contract with a dealer in Boston on this specification, not only for bituminous but for anthracite coal as well. However, the contract is modified with respect to anthracite screenings, to buy on an ash basis, making penalties and paying premiums on the ash content alone, establishing a scale of corrections which takes into account the difference in value to the consumer for variations both in ash and thermal units.

The President. THE PRESIDENT.—In thirty years' experience in trying to get materials according to specification and making specifications, we have run across this trouble with materials; namely that some parties do not care to bid. But we have made use of all sorts of devices to get around this difficulty. I remember in one case the purchasing agent, who was thoroughly aroused and interested in the matter, sent for a certain party and said: "Make your material according to this specification and charge us for it." We worked on that basis in that article for six or eight months. Those whom we had been buying from previously lost their business, of course. After a little they came around and inquired about the course. Now it is very rare that we run up absolutely and positively against a refusal.

Mr. Lesley. MR. R. W. LESLEY.—I think the coal people are going through what we did in the cement business many years ago. In those days material was sold by brand only, but gradually specifications came in and the material was improved to meet them. At first every man made his own specification and at one time there were probably a thousand different varieties of specifications in force in the country. Then, through our Society, a new Standard Specification was prepared of which some forty thousand copies have been sent out and which has become, practically, generally adopted. This year there will be over 50,000,000 barrels of cement sold in the United States—not anything in comparison with the number of tons of coal—but I believe at least seventy per cent. of it will be sold on specification. I think so far as our industry is concerned, we have gone through the specification troubles; I think the iron men have gone through it, and probably the coal men will have to go through it as we have done. Mr. Lesley.

MR. KINKEAD.—I think the coal dealers who seemed the most ready to work to specification and thermal units were those who had coal tested and analyzed at the exposition in St. Louis. They knew what they were making and were willing to consider it. Mr. Kinkead.

THE PRESIDENT.—I should like to emphasize one point; namely, a good specification, honestly enforced, is a protection to the best men in the trade. The man who has good material is not brought in competition with the man who has inferior material, where price only counts. The President.

MR. VOORHEES.—Several large bituminous producers have stated that a specification of this character is very much to their advantage, as it eliminates inferior coals. Mr. Voorhees.

MR. H. E. DILLER.—Mr. Kinkead said the coal miners who had their coal tested at the St. Louis Exposition and knew what they were doing would sell under that contract. But they would probably make a price which would pay them well for the extra trouble and for having good coal; whereas the purchaser who has his coal tested himself can very shortly find out from what company he is getting the best coal and can place his order with them, without paying any extra penalties. This is because the coal miners do not pay much attention to the quality of their coal. It seems to me the consumer gets along better without a specification if he has his coal well looked after. Mr. Diller.

MR. VOORHEES.—In reply to this last speaker, iron ore is bought on the metallic content. The percentage of sulphur and phosphorus further affecting its value. It seems to me this method of buying ore on specification, which is used in most furnaces, could be used on coal. It may not come to-day or to-morrow, but it is bound to come. Mr. Voorhees.

MR. DILLER.—What I mean is that without a specification the consumer has an advantage. It seems to me it would be an advantage to the coal dealer who has a good coal, to get specifications. Mr. Diller.

MR. VOORHEES.—Why should not the consumer have it rather than the operator? If not the advantage is all to the operator. Mr. Voorhees.

MR. RANDALL.—I think the point of view of most of the speakers is that of the local situation. I might say that from a Mr. Randall.

Mr. Randall. general knowledge of the field, I believe that the whole proposition resolves itself into how much competition there may be in the market, and how easy it is to buy coal on specification. If you go to a city like Chicago, where coal is received from West Virginia, Pennsylvania, Ohio, Indiana, Illinois, Kentucky and Iowa, you will find they are buying something like a million tons of coal on that basis, a specification of British thermal units and ash. On the other hand, in Boston, where the railroads have got the coal-market rather cornered, that is, so far as the location of the mines is concerned since it is not profitable to ship coal beyond a certain distance, it has either got to come by boat from far South or by certain lines of railroad, and the coal dealers naturally get their coal from certain districts. There is not very much competition, therefore, as compared with places like Chicago and some other centers. This I think, explains the difficulty in the purchase of coal.

Mr. Little. MR. LITTLE.—You may be interested to know, however, that the manager of one of our largest local companies, who at first said he would throw any orders in the waste-basket—told me later that he was beginning to wonder whether after all the inspection method was not one which had very great advantages from his point of view. "In fact," he said, "I don't know but what it might be good business policy for me to have all of my coal inspected and tested and to sell it as inspected and tested coal."

Mr. Bement. MR. A. BEMENT (by letter).—The method of valuing coal according to the net British Thermal Unit basis, which originated in Chicago, and which the author quotes in full, is probably the most exact scheme thus far proposed. Abbott, however, has shown* that the size of the pieces of coal has a marked influence upon the value of the fuel; likewise the ash operates not only to displace a relative amount of heat-producing matter, but in addition its presence causes a less proportionate realization in useful work of the heat that is in the fuel. With screenings the size of coal is a matter of considerable importance, therefore the writer has seen fit to insert these considerations in the formula used to calculate the net heating power, thereby producing a value which may be designated as the Net Effective Heating Power Value as follows:—Multiply the number of British Thermal

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* *Journal Western Society of Engineers*, Vol. XI, p. 529.

Mr. Bement.

Units per pound of dry coal by the per cent. of moisture (expressed in decimals); subtract the product so found from the number of British Thermal Units per pound of dry coal; multiply by the required value given in the accompanying Table I (expressed in decimals); multiply this new product by 2000 and divide by the contract rate per ton (expressed in cents), plus one-half of the ash percentage (expressed as cents).

TABLE I.—Values for 1¼-in. Coal Screenings.

Per Cent. of Coal that will Pass Through Screen having ¼-in. Round Perforations.	Per Cent. of Ash in Coal as Delivered.																		
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	100	99	98	96	95	94	92	91	89	88	86	84	82	80	78	76	73	70	67
32	98	97	96	94	93	92	90	89	87	86	84	82	80	78	76	74	71	68	65
33	95	95	94	92	91	90	88	87	85	84	82	80	78	76	74	72	69	66	63
34	94	93	92	90	89	88	86	85	83	82	80	78	76	74	72	70	67	64	61
35	93	92	91	89	88	87	85	84	82	81	79	77	75	73	71	69	66	63	60
36	91	90	89	87	86	85	83	82	80	79	77	75	73	71	69	67	64	61	58
37	90	89	88	86	85	84	82	81	79	78	75	74	72	70	68	66	63	60	57
38	88	87	86	84	83	82	80	79	77	76	74	72	70	68	66	64	61	58	55
39	87	85	85	83	82	81	79	78	76	75	73	71	69	67	65	63	60	57	54
40	85	84	83	81	80	79	77	76	74	73	71	69	67	65	63	61	58	55	52
41	83	82	81	79	78	77	75	74	72	71	69	67	65	63	61	59	56	53	50
42	82	81	80	78	77	76	74	73	71	70	68	66	64	62	60	58	55	52	49
43	80	79	78	76	75	74	72	71	69	68	66	64	62	60	58	56	53	50	47
44	78	77	76	74	73	72	70	69	67	66	64	62	60	58	56	54	51	48	45
45	77	76	75	73	72	71	69	68	66	65	63	61	59	57	55	53	50	47	44
46	75	74	73	71	70	69	67	66	64	63	61	59	57	55	53	51	48	45	42
47	74	73	72	70	69	68	66	65	63	62	60	58	56	54	52	50	47	44	41
48	72	71	70	68	67	66	64	63	61	60	58	56	54	52	50	48	45	42	39
49	71	70	69	67	66	65	63	62	60	59	57	55	53	51	49	47	44	41	38
50	69	68	67	65	64	63	61	60	58	57	55	53	51	49	47	45	42	39	36
51	67	65	65	63	62	61	59	58	56	55	53	51	49	47	45	43	40	37	34
52	65	65	64	62	61	60	58	57	55	54	52	50	48	46	44	42	39	36	33
53	64	63	62	60	59	58	56	55	53	52	50	48	46	44	42	40	37	34	31
54	62	61	60	58	57	56	54	53	51	50	48	46	44	42	40	38	35	32	29
55	61	60	59	57	56	55	53	52	50	49	47	45	43	41	39	37	34	31	28
56	59	58	57	55	54	53	51	50	48	47	45	43	41	39	37	35	32	29	26
57	58	57	56	54	53	52	50	49	47	46	44	42	40	38	36	34	30	28	25
58	56	55	54	52	51	50	48	47	45	44	42	40	38	36	34	32	29	26	23
59	54	53	52	50	49	48	46	45	43	42	40	38	36	34	32	30	27	24	21
60	53	52	51	49	48	47	45	44	42	41	39	37	35	33	31	29	26	23	20

And to determine the value of the coal delivered, the calculation is as follows: Multiply the number of British Thermal Units delivered per pound of dry coal by the per cent. of moisture delivered (expressed in decimals); subtract the product so found from the number of British Thermal Units delivered per pound of dry coal; multiply by the required value given in Table I (expressed in decimals); multiply the remainder by 2000; divide this product by the contract guarantee; from this quotient (expressed as dollars and cents) subtract one-half of the ash percentage delivered (expressed as cents).

Table I is prepared upon the assumption that 12 per cent. of

Mr. Bement. ash in the moist fuel composition as applied in the Eastern Interior Coal Basin, is as low as could be expected; or, in other words, it shows the best efforts of the producer; and that a less quantity than 31 per cent. of dust through a $\frac{1}{4}$-in. perforation is not desirable in $1\frac{1}{4}$-in. screenings. These considerations, however, lead to a very much simpler form for valuing screenings, based upon the assumption that the heating power and moisture content may be treated as constants, therefore the value of the screenings delivered may be determined by multiplying the contract price per ton by the figure expressed in decimals which appears in Table I.

It is difficult to understand the intention of the scheme devised by the Geological Survey and now used by the Government in purchasing fuel. It appears that provision has been made for the reduction of or increase in price in proportion to the decrease or excess of the heating power present. The deduction for ash content, however, is difficult to understand. The exact wording is as follows: "The economic value of a fuel is affected by the actual amount of combustible matter it contains, as determined by its heating value shown in British Thermal Units per pound of fuel, and also by other factors, among which is its ash content. The ash content not only lowers the heating value and decreases the capacity of the furnace, but also materially increases the cost of handling the coal, the labor of firing, and the cost of the removal of ashes, etc."

According to the above quotation, the only certainty is, the intimation that the presence of excessive ash entails additional cost for its removal. If this is the proper interpretation, then the valuing method of the Survey is at fault as the following will show:

COMPARISON BETWEEN GEOLOGICAL SURVEY AND B. T. U. FOR ONE CENT BASIS.

	Guaranteed Composition.	Delivered Composition.	
		Based on B. T. U. for one cent.	Based on Geological Survey Method.
Moisture	10.00	10.00	10.00
Ash in coal as delivered	8.10	13.60	13.60
Heating power in B. T. U.	11,875	11,078	11,078
B. T. U. for one cent	98,958	.....	.....
Price per ton (contract rate)	$2.40	.....	.....
Delivered value	$2.40	$2.239	$2.119

Mr. Bement. The above would indicate that the Geological Survey method intends to impose an additional reduction larger than that required by absence in heating power, and a comparison between the scheme of valuing on the net B. T. U. basis follows:

Comparison Between Geological Survey and Net B. T. U. for One Cent Basis.

	Guaranteed Composition.	Delivered Composition.	
		Based on net B. T. U. for one cent.	Based on Geological Survey Method.
Moisture	10.00	10.00	10.00
Ash in coal as delivered	8.10	13.60	13.60
Heating power in B. T. U	11,875	11,078	11,078
Net B. T. U. for one cent	97,315	.....	.....
Price per ton (contract rate)	$2.40	.....	.....
Delivered value	$2.40	$2.208	$2.119

which shows that the Geological Survey method imposes a penalty which is excessive, unless the reduction for ash is expected to cover damage caused by its presence, in addition to the expense entailed for its removal. Whether or not the Geological Survey considers its scheme of valuing as far as ash is concerned the one best suited to apply to average conditions does not appear.

The problem of coal production and utilization is an extremely complicated one not very well understood, and the practice of dealing between seller and buyer upon a guarantee basis is one well calculated to dispel many of the uncertainties now existing, and the general tendency is to produce a better understanding upon the part of both parties to the transaction. Considerable experience has shown the writer that when the seller is advised by competent authority in making guarantees, that it frequently leads to the purchaser wishing to buy directly without guarantee, and in the case of one of the writer's most important clients, using a very large amount of coal, no guarantee is expected, as the client knows more about the coal composition and mining conditions in the territory in which it purchases than do the operators therein, having thoroughly studied the matter and arrived at definite conclusions.

THE EFFECT OF MOISTURE AND OTHER EXTRINSIC FACTORS UPON THE STRENGTH OF WOOD.

By Harry Donald Tiemann.

Many factors which have little or no significance in testing metals must be taken into consideration in testing wood. These factors may be divided into two classes: *First*, those which are inimical to the particular stick in question, and do not vary from time to time, namely, structure, density, grain, heart or sapwood, and defects of all kinds. These may be termed *inherent* factors. In a way they apply to metals as well as wood. *Second*, there are factors which cause more or less temporary variations in the strength of the selfsame stick, which may be termed *extrinsic* factors, since the result produced is not primarily due to the wood itself, but to the conditions to which the wood is subjected. Some of these factors have little or no effect whatever upon the strength of metals.

Of all the extrinsic factors which may occur under ordinary circumstances, *moisture* is by far the most influential. Among the other extrinsic factors may be mentioned, temperature, speed of loading, effect of treatments to which the wood may have been subjected, such as steaming, drying at high temperatures, etc., and the effect of liquids other than water. In discussing the effect of these factors no consideration is given to the mechanical injuries produced, such for instance, as checks produced in "case-hardening," warping, etc., but the discussion deals solely with their physical effect upon the wood substance.

In testing wood it must be remembered that we are dealing with an exceedingly complex fabric which depends for its properties not only upon the composing material but equally upon the form and arrangement of its structural elements. Even the substances of which the various elements are composed are so complex that they have not yet been satisfactorily analyzed chemically.

When one realizes, as I shall endeavor to demonstrate, that

The cuts used in this paper are from Bulletin 70, *Forest Service*, U. S. Department of Agriculture.

the strength of green wood may be increased in some species over fourfold (400 per cent.) simply by extracting the moisture, it certainly is astonishing to find how little attention has been paid in the past to the question of moisture content when making tests upon wood. The majority of results obtained, prior to the work begun by the United States Division of Forestry (now Forest Service) in 1892, are tabulated with absolutely no reference to the moisture condition under which the tests were made except in some cases where a statement is made that the wood was "seasoned" or otherwise. The futility of using any such tables is obvious. By testing a dry piece of one of the weakest species and a wet piece of the strongest, the results might easily show to the advantage of the weakest wood.

In the case of large timbers, however, the foregoing statements do not necessarily apply, for two reasons. *In the first place* it requires many months, and even years, for a timber the size of a bridge-stringer to season sufficiently for much increase in strength to occur. Consequently tests made on large timbers of this kind are usually made in the "green" condition and are therefore comparable; for, as I will show, there is a definite moisture degree called the "fiber-saturation point", beyond which, it matters not how wet the wood is, no significant change in strength occurs. *In the second place*, large timbers are very apt to be injured mechanically in drying, due to unavoidable checking, which offsets more or less completely the increase in strength which otherwise would take place. For these reasons it has been concluded that for large timbers in the species so far tested, no increase in strength should be counted upon above that of the original green wood. But in all tests upon small sizes the moisture factor must be given full weight; and the indicated increase in strength may be counted upon in practice, when no mechanical injury has been produced in the drying. Under normal conditions, wood, of course, will not remain in the perfectly dry condition, but will regain in the neighborhood of 12 per cent. of moisture, according to the humidity of the air, so that the practical increase in strength is less than half the possible amount attainable by complete drying.

Reviewing briefly the literature upon the subject, we find some notice paid to moisture prior to 1848 when the work of Chevandier and Wertheim was published in French. These investigators realized that moisture influenced the strength of wood, and made note of four general conditions of seasoning, in their tests, fresh, partly dry, well seasoned, and kiln dry. J. Baushinger, of Munich, made a few experiments on the moisture-strength relation of Scotch pine, prior to 1883, but entirely disregarded the fiber-saturation point.

When the timber tests were undertaken by the United States Department of Agriculture in 1891, provision was made in the plan for a study of the moisture-strength relation, and a partial study of the subject was made by Prof. Johnson. The results are given in Bulletin No. 8 of the Division of Forestry and also in his work upon the "Materials of Construction." Prof. Johnson takes note of the existence of what I have called the "fiber-saturation point," but strangely enough does not apply the reasoning in his curves.

More recently, an excellent series of moisture-strength curves has been derived for spruce, by Gabriel Janka, Mariabrunn, Germany, which are co-ordinated with the dry specific gravity as well. They are published in 1904 in Baumaterialenkunde, Heft 17, September. Here, also, the fiber-saturation point has been disregarded.

When the timber tests were again taken up, according to the comprehensive plan described in a paper by Dr. W. K. Hatt in the Proceedings of this Society (Vol. III, p. 308), it was decided to make an exhaustive study of this subject, and thus place all timber tests upon a standard basis as to moisture. This investigation the writer has been conducting for the last four years, at the Forest Service Testing Laboratory run in co-operation with the Yale Forest School, New Haven, Conn. A detailed account of the experiments and results obtained up to 1905 is given in Bulletin 70 of the Forest Service, "The Effect of Moisture upon the Strength and Stiffness of Wood," and a brief summary including more recent determinations in Circular 108.

By means of these results, strength values obtained at any known moisture degree may be converted into equivalent values at a standard or any desired moisture degree, and thus all tests made comparable.

Moisture exists in green or wet wood in two conditions, that which is contained in the cell cavities or pores of the woodlike honey in a honeycomb, and that which is imbibed by the substances of which the cells are composed. The former or "free water" evidently exerts little or no direct influence upon the strength,

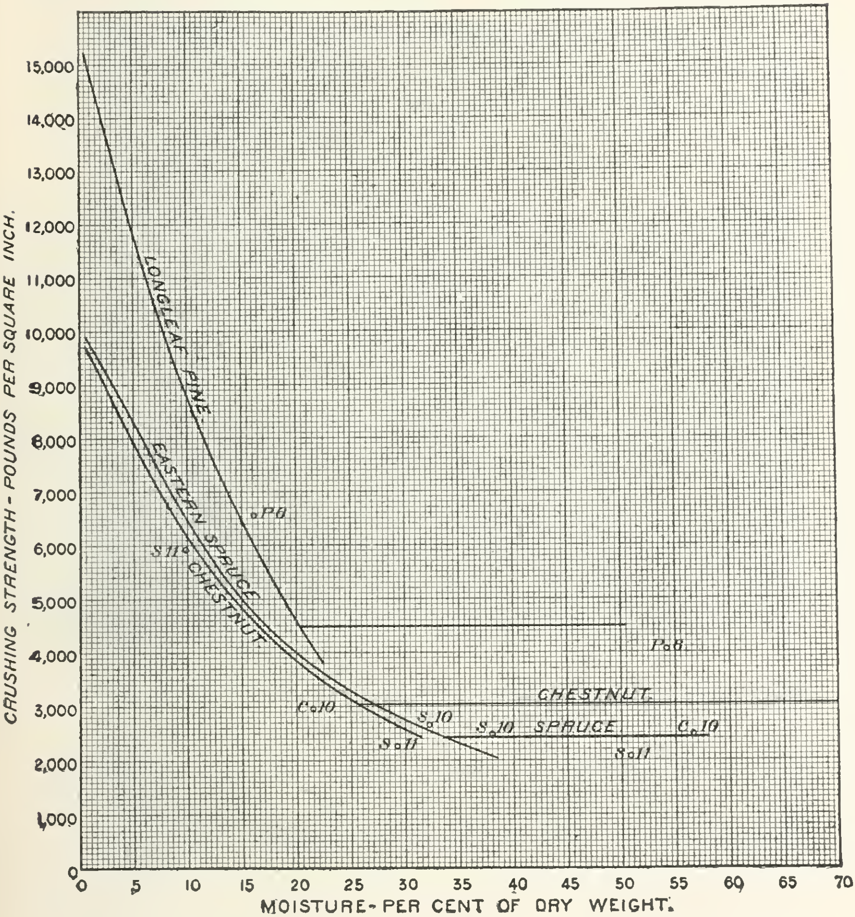


FIG. 4.—Variation in Strength with Moisture in Compression Parallel to Grain.

which is affected only by the "imbibed" water. In drying a stick of green or wet wood, the free water must evaporate before the cell walls begin to dry. No increase in strength occurs during this process, but the moment the moisture begins to be extracted from the cell walls, that moment the strength begins to increase rapidly. At this point the wood likewise begins to shrink. This is the critical moisture degree which I have called the *fiber-saturation point.*

Now if the relation between moisture and strength be plotted graphically, expressing the moisture content in per cent. of the dry weight as abscissæ, and the strength as ordinates, we will have first, starting with a wet piece of wood, a long horizontal line. This line abruptly terminates at the fiber-saturation point where it touches the true moisture-strength curve. The form of the curve is concave, the strength increasing more rapidly as the wood becomes drier, as is clearly seen in the diagram.

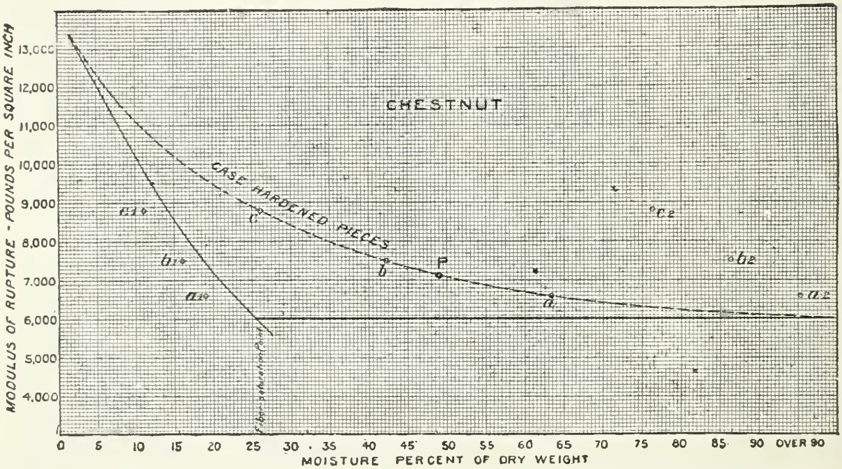


FIG. 5.—Effect of Casehardening upon the Form of the Moisture-Strength Curve for Bending.

The true fiber-saturation point is easily obscured. Since there is no direct way of differentiating between the imbibed and the free water, in the moisture determinations, and the curve simply rounded off above. This must evidently occur when the moisture is unevenly distributed and part of the fibers drier than the fiber-saturation point, for in such a condition the strength will show an increase while the average moisture may be far beyond that of the fiber-saturation point. This is well shown in the curves obtained for pieces purposely *case-hardened.*

Many factors affect the fiber-saturation point. Heating the water in which wood is soaking increases the absorptive capacity, consequently reducing the strength and lowering this point in the moisture-strength curve. Cooling the water produces an opposite effect. Simple air-drying alters it slightly, so that air-dried wood which is re-soaked is weaker than the original green wood. Subjection to high temperatures, steam, and other treatments have marked permanent influence upon the fiber-saturation point, the degree of change varying with the species and intensity and kind of treatment.

In the following table are given the moisture per cents at the fiber-saturation point for several species:

FIBER-SATURATION POINT DETERMINATIONS.

Species.	Condition.	No. of tests.	Average specific gravity kiln-dry wood.	Moisture per cent. at fiber-saturation point (average).
Longleaf pine	Green	40	.62	25
Loblolly pine	Green	24	.59	23
heartwood	Air-dry	80	.67	24
Loblolly pine	Green	72	.47	24
sapwood	Air-dry	80	.55	26
Norway pine	Heartwood	121	.42	30
green	Sapwood	88	.44	28
Red spruce	Green	40	.38	31
Tamarack	Green	121	.54	30
Red fir	Green	65	.58	23
Western hemlock	Green	144	.54	29
Chestnut	Green	40	.48	25
White ash	Green	49	.79	20
Red gum	Air-dry	45	.52	25
Red spruce	Air-dry	120	.45	30 to 32
	Superheated	120	.44	24 to 25
Tamarack	Air-dry	120	.60	30 to 32
	Superheated	80	.61	24 to 25
Chestnut	Air-dry	120	.48	26 to 27
	Superheated	120	.46	22 to 24

In our investigations, the principal tests and those giving the most uniform results have been compression parallel to grain upon specimens 2 by 2 by 6 inches and smaller. Bending and shearing tests have also been made upon a number of species and a few in compression at right angles to grain.

Suitable green material is selected, cut into strips of the required size, which are chosen with great care so as to have comparative specimens as identical as possible, and free from defects. Each strip, in the case of the compression tests, is then cut into a series of specimens which are numbered consecutively, the series from adjacent strips being numbered in reverse order, to eliminate effect of position. Each specimen in a series is brought to a different degree of seasoning and then tested. From seven to sixteen series have been used for each determination. Specimens from the several series having the same consecutive numbers are treated alike and designated a set.

The aim is to eliminate all variable quantities except the two under investigation. For this reason, great care is required in selecting, preparing, and treating the specimens. The size is an important consideration. The specimens must be small enough to allow of uniform treatment and quality, and large enough to comport with all measurements and testing operations. The preparation and treatment of the specimens constitutes the main part of the problem. It is of the utmost importance, since wood is such an exceedingly mutable material, not to neglect a single variable factor, and this is the basis upon which the results must stand or fall. Consequently a great many correlated studies must be made. For example, it has been found that wood which has been allowed to dry or even partially air-dry, and is then re-soaked, is not comparable with the fresh green material or that which has been soaked without drying. Neither are two sticks comparable which have been soaking at different temperatures, and so on.

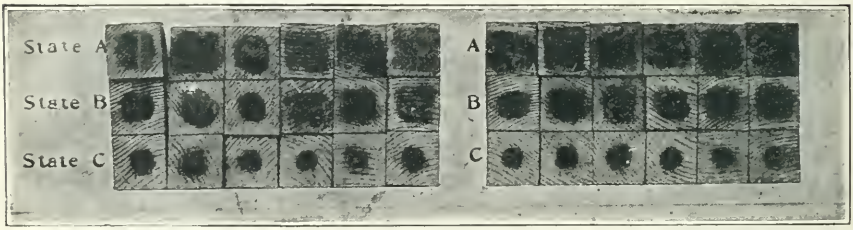


FIG. 6.—Three Degrees of Drying. Sections of Specimens Used in Obtaining Effect of Case Hardening in Drying.

The moisture content is determined by cutting a cross-sectional disc at the point of failure, and drying to constant weight at 95° C. The loss in weight times 100, divided by the dry weight of the disc is the per cent. of moisture used. The fiber-saturation point is determined separately by tests upon very small blocks; and the point located upon the moisture-strength curves. The curves vary considerably with different species, and also with the previous treatment to which the wood has been subjected, but all have the

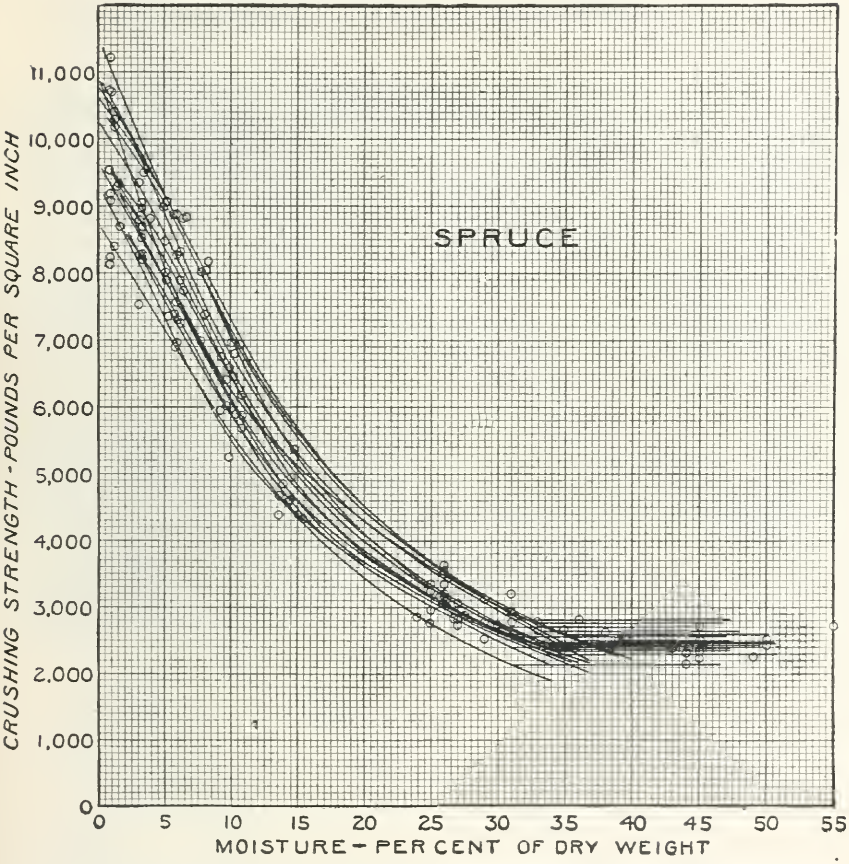


FIG. 7.—Individual Moisture-Strength Curves for Sixteen Series of Spruce in Compression Parallel to Grain.

general concave form, as will be seen in the diagrams. These diagrams are for the green wood which has not been previously dried.

The following are the ratios of increase in strength over that of green wood for three conditions, kiln-dry, air-dry, and re-soaked after kiln-drying:

Species.	Kiln-dry, 3½ per cent. moisture.	Air-dry, 12 per cent. moisture.	Re-soaked, wet.
Red spruce	3.7	2.4	.91
Longleaf pine	2.9	1.7	.90
Loblolly pine—heartwood	3.1	2.0	..
Loblolly pine—sapwood	3.0	1.7	.90
Norway pine	3.4	2.0	.89
Tamarack	3.2	1.9	.92
Red fir	2.6	1.7	..
Chestnut	2.8	1.8	.82

In the oven-dry state, these ratios are proportionately greater. This increase in strength is very slightly due to shrinkage in area, since the values are per unit of area, and there are necessarily more fibers in a unit area of dry than of green wood. The amount due to this shrinkage is, however, rather insignificant compared to the total increase in strength. This reducing factor in compression tests is about 0.9. The given kiln-dry values should be multiplied by this factor to show how much the self-same stick would increase in strength. For bending tests the factor is about 0.88.

The bending strength (modulus of rupture) follows a similar law, but to a slightly less degree. So also do the other strength values, as stress at elastic limit and modulus elasticity. The shearing strength parallel to the grain is an extremely variable quantity and while it sometimes increases with drying, it often times does not, and without any apparent cause. The variability is probably accounted for by internal strains due to unequal shrinkage of the fibers in drying, causing the beginnings of longitudinal checks in the cell walls themselves. Of course, where visible checks occur, loss in shearing strength is self-evident, but we are speaking of the physical effects, and would cull all such cases where mechanical injury has been done to the wood. It is consequently unsafe to count upon any gain in the longitudinal shearing strength by drying above that of the green material even when there is no apparent cause for weakness.

The following table will give an idea of the comparative ratios from the wet to the kiln-dry condition, of the several kinds of resistances of wood to applied forces:

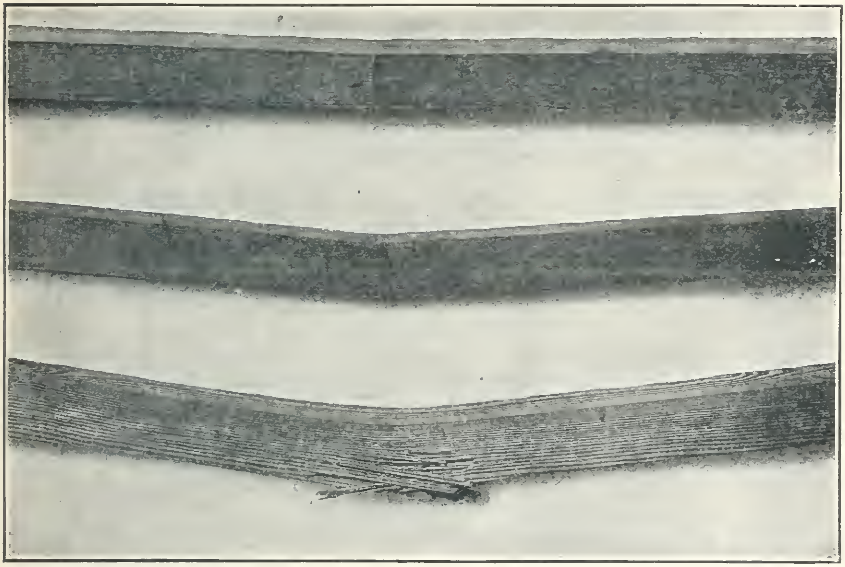


FIG. 8.—Manner of Failure under Bending Tests of Green, Air-dry and Kiln-dry Longleaf Pine.

Kind of stress.	Longleaf pine.	Red spruce.	Chestnut.
Compression strength parallel to grain	2.9	3.7	2.8
Stress at elastic limit, compression parallel to grain	2.6	3.8	2.4
Modulus rupture, bending	2.5	2.8	2.1
Stress at elastic limit, bending	2.9	2.9	2.3
Modulus elasticity, bending	1.6	1.4	1.4
Compression strength at right angles to grain at 3 per cent. distortion	...	2.6	...
Shearing parallel to grain (very variable)	2.0	2.0	1.6

Assuming the strength to vary directly with the density of dry wood, the following equation will give approximately the crushing strength per square inch of perfect wood of normal longleaf pine:

$$C = G\ (22.1\ p^2 - 1335\ p + 25610).$$

Where C = crushing strength in pounds per square inch.
G = specific gravity of perfectly dry wood.
P = per cent. of moisture, by disc method.

It may be interesting to remark here that, *weight* for *weight*, dry red spruce is as strong and stiff as good quality steel and considerably stronger than cast iron. In structural timbers, *weight* for *weight*, spruce and pine excel the hardwoods in strength.

There are a great many problems closely allied to the question of moisture which have barely been touched upon by experimenters. Here is a large field of investigation of great importance to the users of wood. The Forest Service is undertaking the solution of many of these at the Yale Forest School Laboratory. The moisture-strength relation of wood is proving to be more and more an intricate problem. Experiments are now under way to determine the fundamental laws of the influence of temperature and time in drying wood under various conditions, such as saturated steam, superheated steam, dry air, compressed air, and vacuum. When completed it is hoped that the best temperature and method of drying for any particular purpose can be determined for each species, also the danger limits in the intensity of the treatments. To obtain the majority of these results will require some years. Thus far the experiments have shown that certain high-temperature treatments reduce the hygroscopicity of wood, thus causing reduced swelling and shrinkage, and on account of the permanent reduction in moisture when the wood is exposed to normal air, a considerable increase in strength occurs. When, however, the wood is re-soaked after treatment, although the absorption of water is diminished by some treatments, the strength is reduced.

These experiments have also direct bearing upon the effect of the temperatures and steam pressures used in the preservative treatment of wood.

The effect of long-time soaking in water has not been thoroughly studied, although it has been fairly well established that the soaking process of itself does not reduce the strength. Many tests go to show that air-dried wood, although at first reduced below the original green strength by re-soaking, gradually recovers after soaking several months. Special tests made upon red oak soaked while green for three months and one year respectively, show a gain of 15 per cent. in the crushing strength, with the longer period of soaking. Another set soaked two months and one year respectively, show a gain of 5.5 per cent. It is possible that this increase is due in part at least, to differences in temperature of the water, since the earlier tests were made in June and July when the water was 68° F. and the later tests in April at 50° F.

This brings us to the question of temperature of soaking. Not enough experiments have been made in this line to derive the law, but it has been proved beyond question that the warmer the water, the weaker the wood. Boiling reduces the strength of green wood some 40 per cent. below that of wood soaked at normal temperatures, while on the other hand, freezing increases it 10 per cent. or more, varying with the species. It would appear desirable therefore, to correct tests for temperature as well as for moisture.

Time will not allow of further mention of the many other related factors which influence the strength of wood, and I will therefore close with a brief summary of the main points.

(1) Moisture has a great effect upon the strength of wood, which may be increased by artificial drying over four times its original green strength, but in the ordinary air-dry state, it is from 1½ to 2½ times as strong. This does not apply to large timbers but to sticks under 4 inches thick when no mechanical injury has occurred in drying.

(2) There is a definite moisture condition called the fiber-saturation point varying from 20 to 30 per cent. beyond which the cell walls cease to imbibe water, although free water may continue to enter the pores. Here swelling ceases and the strength becomes constant under given conditions.

(3) Soaking wood at uniform temperature does not reduce the strength of green wood, but warming the water does reduce it.

(4) Any kind of drying reduces the strength when re-soaked as compared with that of the original green wood.

(5) Certain methods of drying at high temperatures reduce the hygroscopicity and consequently the swelling and shrinkage;

and when in the air-dry condition the strength is increased over that of normal air-dry wood, but when re-soaked it is reduced below that of green wood.

(6) All tests on wood should be standardized at least for moisture, temperature and speed of loading.

A TEST OF WOODEN AND REINFORCED CONCRETE TELEGRAPH POLES.

By Robert A. Cummings.

About a year ago the author designed and constructed a few reinforced concrete telegraph poles for the Pennsylvania Railroad Lines West which have given satisfactory service.

They were designed with a margin of safety of three, to carry fifty telegraph wires, coated with one-half inch of ice, and exposed to a lateral wind pressure of thirty pounds per square foot. The poles were thirty feet long and spaced one hundred feet apart. These conditions are approximately equivalent to a concentrated loading of 1,000 pounds placed near the end of the pole. The poles were made hollow to reduce their weight in transportation. Tests were made to verify the strength of the reinforced concrete poles and to compare them with the strength of Pennsylvania Railroad standard white cedar poles of similar dimensions.

The rather novel problem of testing poles in a vertical position with a sufficient degree of accuracy was accompanied by a very limited appropriation of funds. Hence, the special testing apparatus devised by the author to measure the loads and deflections for each pole.

The following is a description of the apparatus and method of testing:

The load was applied through a band ten inches from the top of the pole by means of two three-quarter inch wire ropes which passed over two twelve-inch sheaves near the end of an inclined A frame. These ropes received the hook supporting a differential chain hoist of five-ton capacity. The base of the A frame rested freely upon the front edge of the concrete foundation and inclined away from the poles at an angle of 45°. A pulley suspended from the extreme end of the A frame carried the differential hoist, the lever arm and counterweight.

The initial load applied at the top of the pole was thus reduced to fifty pounds by means of the counterweight. The total amount of applied load was measured by a simple lever apparatus. One

RESULTS OF TESTS.

Pole.	Application of load. No.	Deflection at top, inches.	Load, pounds.	Deflection at bottom, inches.	Time.	Remarks.
	1	$3\frac{3}{4}$	1,830	$\frac{1}{32}$	3:17	
		$5\frac{3}{4}$	2,230	$\frac{1}{16}$	3:18	
OCTAGONAL CONCRETE.	2	$\frac{1}{2}$	50	$\frac{1}{32}$		Permanent deflection—$\frac{1}{2}$ inch.
		8	2,630	$\frac{1}{8}$	3:19	
		$11\frac{3}{4}$	3,030	$\frac{3}{16}$	3:20	Cracks No. 1 and No. 2.
	3	$1\frac{1}{4}$	50	$\frac{1}{16}$		Permanent deflection—2 inches.
		$14\frac{1}{4}$	3,430	$\frac{1}{4}$	3:24	Cracks No. 3 and No. 4.
		18	3,210	$\frac{3}{8}$	3:25	Crack No. 5 crushed at bottom.
		$25\frac{1}{2}$	3,150	$\frac{3}{4}$	3:26	Pole broke at ground level.
SQUARE CONCRETE.	1	$\frac{3}{4}$	50		2:02	
		$2\frac{1}{2}$	1,830		2:04	
		$3\frac{1}{2}$	2,230		2:08	
	2	$\frac{3}{4}$	50			Permanent deflection—1 inch.
		$4\frac{9}{16}$	2,630		2:10	
		$8\frac{1}{2}$	3,030	$\frac{1}{16}$	2:11	
	3	$3\frac{1}{2}$	50			
		31	3,290			
		$34\frac{1}{2}$	3,430	$\frac{1}{8}$	2:14	Crack No. 1.
	4	$21\frac{1}{4}$	50			Permanent deflection—22 inches. Cracks No. 2, No. 3, No. 4, pole crushed.
		39	3,690		2:19	Cracked at ground level.
WOODEN NO. 2.	1	20	1,830		11:50	
		$22\frac{1}{4}$	2,230		11:51	
		29	2,630		11:52	
		35	2,870		11:53	First crack.
		$36\frac{1}{2}$	2,950		11:54	
		$38\frac{1}{2}$	3,030		11:55	
		50	3,370		11:56	
		56	3,430		11:57	
		66	3,494		12:00	Pole broke suddenly.
WOODEN NO. 1.	1	14	172			
		37	2,230			
		47	2,530		11:03	Pole broke suddenly.

end of the lever arm was supported on the platform of a 2,500 pound capacity weighing scale, while the other end was attached to the differential chain hoist.

The lever acted through a rocker fulcrum suitably supported. The load was applied or released by operating the differential hoist. In applying the load the hoist would reduce the distance between the hooks at any rate of speed desired. A graduated rule was fastened at the top of the pole being tested and extended back parallel with the line of poles crossing an arm containing a gauge pin from which point deflections were read. This arm was nailed to a rigidly braced upright erected near the rear telegraph pole. Deflections were also read twelve inches above the foundations by means of a movable rule.

The platform for supporting the observer reading deflections at top of poles was suspended from a nearby bridge.

For general arrangement of apparatus see Fig. 1.

The table published herewith gives the loads and corresponding deflections of four poles tested.

The white cedar poles broke about seven feet above the foundation.

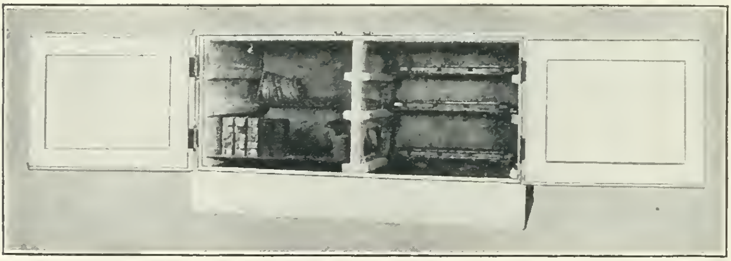
The concrete poles failed by crushing of the concrete in the base of poles at the level of the foundation.

A NOVEL MOIST CLOSET.

By Ernest B. McCready.

A brief description of a moist closet, fully equal to a slate or soapstone closet, and which may be made in any laboratory with a minimum of cost (considering its character) may be of interest.

The closet shown was made of "waste cement" left from testing—all brands mixed—and several samples of natural sand from the same source. The cement was thoroughly mixed, as were the sand samples, so as to insure uniformity in color, etc. The mortar was mixed 1 to 2 and wet enough to be readily filled into and tamped down in a $\frac{5}{8}$ in. space. The walls are $1\frac{1}{4}$ in. thick, except the center panels of the doors which are only $\frac{1}{2}$ in. thick. The walls are reinforced with $\frac{1}{2}$ in. mesh galvanized wire netting. The hinges in this closet were specially designed to be imbedded in the walls and doors. Of course, if desired, ordinary strap hinges can be used (except that they should not be of iron), and may be bolted to the doors and walls. The hinge shown is a little more expensive but makes a better appearance.



The dimensions of this closet are practically the same as those of the soapstone closet described by Mr. R. L. Humphrey and illustrated by Taylor and Thompson and others, but shape and size may be varied to suit the space to be occupied or the size of molds used. The necessary forms can readily be made by any carpenter, and consist of an outside form or box without top or bottom and two inside forms or cores which are simply boxes with tops but no bottoms. As the closet is cast face or front down, the top of the forms means the back of the closet. When the forms are in position, there must be 1¼ in. clearance all around each core,—top, bottom and sides. The doors are cast first by filling in a frame of the proper dimensions, laid on a pane of glass or other flat surface which has been oiled. The hinges are placed by marks on the frame and secured thereto by small brads before the mortar is filled in. The same form answers for the two doors by simply reversing the position of the hinges. (If made like those illustrated, the hinges must be "right" and "left.")

When hard enough to stand handling, the two doors are placed, in their proper relation, face down, on a flat surface and the outer box form placed around them. The edges of the doors are covered with several thicknesses of oiled paper and the cement mortar filled in around them level with the doors, making the layer of mortar just 1¼ inches thick. The inside forms are immediately placed in position, open end down and are supported by the doors which are sufficiently hard. If correctly made, they will reach to within 1¼ in. of the top of the outer form and there will be an open space of 1¼ in. all around each core. The mortar is then filled in around and over these cores and smoothed off even with the top edge of the outer form; this top layer forming the back of the closet.

Of course, the placing of the reinforcement adds slightly to the detail of these operations. The doors and the back are filled in two layers with the wire placed between. The wire for the sides—in one piece—is placed in position and kept in the middle by strips of half inch board which are moved along or taken out as the mortar is filled in. The doors may be paneled and their weight reduced by placing in the frame, before and after filling, a piece of plate glass, slate or even wood of the desired shape and thickness. These are removed after the mortar has hardened.

The forms must be thoroughly shellacked and oiled before use. The cores must be put together with screws, entirely from the inside and exposed ends and edges slightly beveled so that they may be removed after the cement has set. The shelf ledges are provided for by longitudinal strips on the ends of the core boxes, in width equal to the distance desired between the ledges. The space between, when filled with mortar, makes the ledge.

The appearance of the closet may be enhanced by thoroughly moistening the green surfaces after the removal of the forms and sifting some neat cement lightly and evenly over the whole from a 50 or 80 mesh sieve.

This closet has been in use a little over a year and has given great satisfaction. It is water-tight and requires no felt lining to maintain a uniform degree of humidity, since the cement walls, themselves take up and distribute moisture. By actual repeated tests, we have found the percentage of saturation on the top shelf to be as high and often a little higher—owing perhaps to a slight difference in temperature—than that at the surface of the water.

A NEW IMPACT MACHINE.

By L. W. Page.

The essential parts of this impact machine, like all others, are a hammer and an anvil. The nature of the work for which it was designed, however, has made it necessary to introduce a number of devices not before employed in impact tests.

The main object of the test is to determine the relative toughness of road building rocks. In the consideration of road materials toughness is understood to mean the power possessed by a material to resist fracture under impact. As the surface of a road is continually subjected to the pounding of traffic, it can be seen that toughness is an important property from the standpoint of the road builder. From the laboratory standpoint the problem is not altogether a simple one, and considerable difficulty has been found in designing a suitable test for measuring the degree to which a rock possesses this property. With homogeneous, structureless, brittle materials, resistance to impact may be due to a relatively low modulus of elasticity combined with high elastic limit. Provided a blow is delivered by a flat striking head with small local damage, on such a material toughness will be almost due wholly to elasticity. In this case there will be a critical energy of blow below which the specimen under test will not be broken by an indefinite number of blows, and in excess of which it will be broken by a single blow. The toughness of a road material in this instance will vary directly as the square of the elastic limit, which equals the ultimate strength and inversely as the modulus of elasticity. In testing such materials under impact it is necessary to apply a number of blows of successively increasing energy, and note the blow causing failure. The machine which I am about to describe involves this principle, and is the result of about fourteen years' work on the subject.

Instead of the hammer falling directly on the test piece it strikes an intervening plunger, and the energy of the blow is con-

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Acknowledgment is made to the *Engineering Record* for the cuts used in this paper.—Ed.

veyed through this plunger to the test piece. As comparative values are sought rather than physical constants, the end of the plunger bearing on the test piece is spherical in shape, thus rendering the energy of the blow splitting in its effect. At present we have in the laboratory of the Office of Public Roads two of these machines, one having a 2-kilogram hammer and a 50-kilogram anvil, a perspective and front view photograph of which is shown in Fig. 1. This machine is used for making routine tests on the toughness of road building rocks, and has a few special devices for this work. The other machine has a 10-kilogram hammer and a 500-kilogram anvil, and is used for larger tests, especially on paving blocks. A front and side elevation of this machine is shown in Fig. 2. In describing this test I will confine my remarks entirely to the smaller machine as it has all the essential parts of the other and a few improvements.

The test for toughness is made on 25 millimeter by 25 millimeter rock cylinders which are cut with a core drill. It can be seen that the blow as delivered through a spherical end plunger approximates as nearly as practicable the blows of traffic, besides this it has the further advantage of not requiring great exactness in getting the two bearing surfaces of the test piece parallel, as the entire load is applied at one point on the upper surface. The test piece is adjusted so that the center of its upper surface is tangent to the spherical end of the plunger, and the plunger is pressed firmly upon the test piece by a spring. The test piece is held on the anvil of the machine by a device which prevents its rebounding when a blow is struck by the hammer, and which keeps the test piece centered.

The hammer, which weighs two kilograms, is raised by a sprocket and chain released automatically by means of an electro-magnet. The test consists of a one centimeter fall of the hammer for the first blow, and an increased fall of one centimeter for each succeeding blow until failure of the test piece occurs. The number of blows required to destroy the test piece is used to represent the toughness of a sample. The variation in results on the same material is very low; only in rare instances does a variation of more than one blow occur.

The machine consists of a 2-kilogram hammer (A), which is guided by two vertical rods (N). The upper end of the hammer

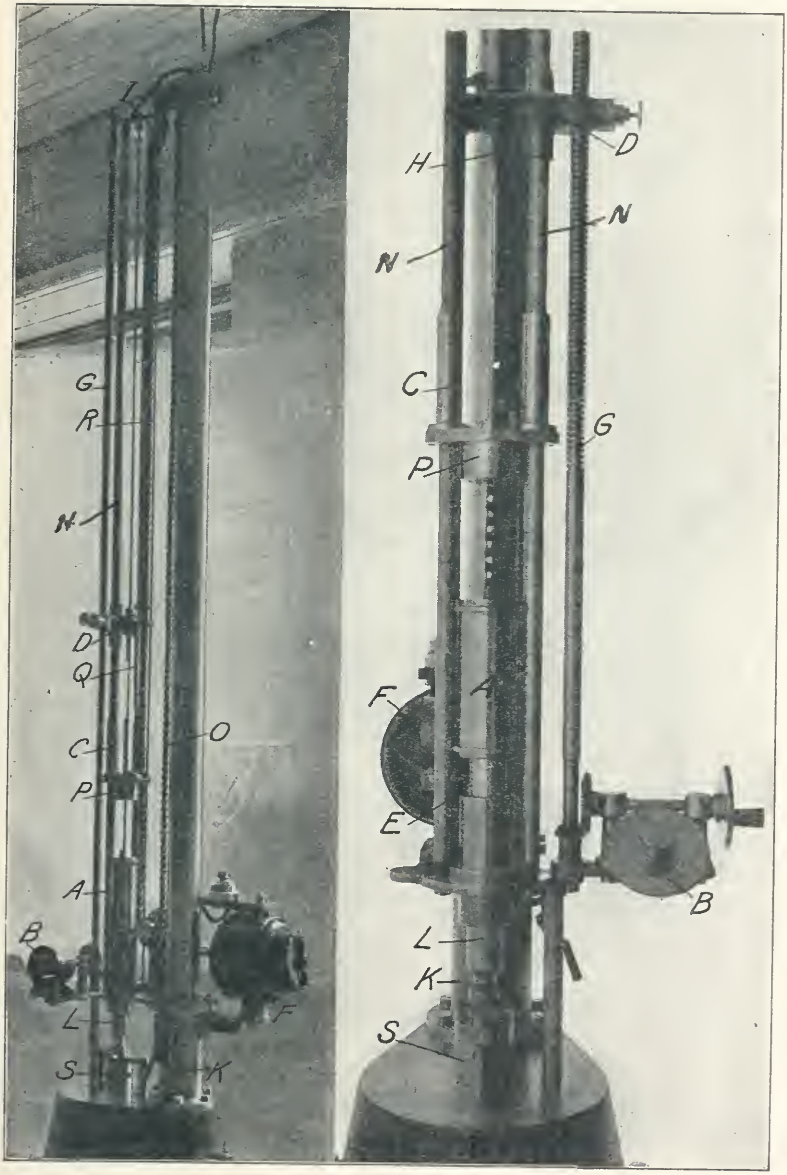

FIG. 1.—Small Machine for Impact Tests.

has a small cone set in it, which fits snugly into a concentric electro-magnet (P), the latter being attached to the lower side of a cross-head (C), which slides freely on the guide rods (N). This cross-head is provided with a slot on its rear side through which a sprocket chain (O) passes. This sprocket chain being supported on the sprocket wheels which are attached to castings at the top (I) and near the base (K) of the machine, which project sufficiently to support the guide rods (N) and other attachments. The lower sprocket wheel is directly connected by a worm gear to an electric motor (F), placed at the rear end of the lower casting (K). The sprocket chain is provided with two small lugs, which when it is being driven by the motor engage a spring bolt attachment which projects inward on either side of the slot on the crosshead (C). This raises the crosshead until tripped by a rod (Q) projecting downward from an upper crosshead (D). When this takes place the crosshead (C) which holds the electro-magnet falls until it comes in contact with the hammer (A). The electro-magnet (P) is supplied with current from the same circuit running motor. The current being conveyed through two small conducting rods running parallel to the guide rods, both being insulated from the rest of the machine. The current passes from one of these conductor rods through a small carbon brush to a make and break attachment (H) on the upper crosshead (D), thence down one of the guide rods through the electro-magnet back to the other conductor rod.

When the crosshead (C) is raised by the lugs on the sprocket chain and the current turned on the magnet, the hammer is lifted until the crosshead (C) comes in contact with the make and break (H) on the crosshead (D) and thus releases the hammer, which falls, striking a plunger (L). This plunger is made of armor piercing steel which has the maximum temper at its lower end, which is spherical in shape. The test piece rests on a counter anvil (S) of hard steel, the plunger resting on its upper surface, which is tangent to it at its center point.

The upper crosshead (D) is raised through any desired height by means of the long revolving screw (G), which is geared at its lower end to a dial (B), on which the height of the make and break attachment, and, therefore, the height of the hammer drop, may be read directly. By means of the revolving dial and screw the

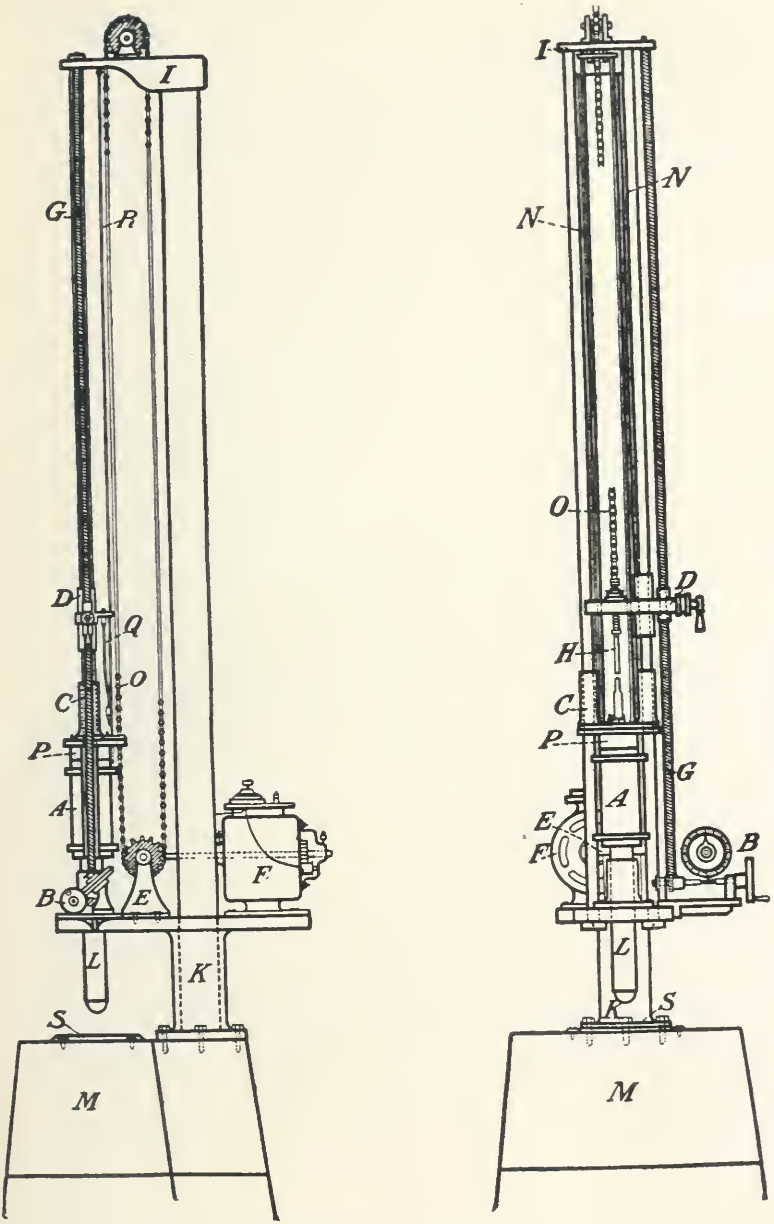

FIG. 2.—Large Machine for Impact Tests.

height of the crosshead may be adjusted by very close approximation to within 1 millimeter.

In order to prevent the crosshead (C) which holds the electromagnet from striking too hard a blow on the hammer when falling, a dash pot was first used, but we have found that a few drops of cylinder oil on the lower end of the guide rods completely prevents this difficulty.

A point of interest in connection with this test, is the fact that many of the test pieces are split into three pieces. Just why this takes place I am unable to explain.

The highest result yet obtained was on a sample of diabase from Pennsylvania. One test piece of this sample broke at a drop of 54 centimeters. Three months later another operator cut and tested another test piece, which broke at 58 centimeters drop. The next highest result was on a fine-grained sandstone from Virginia. One test piece broke at 49 and the other at 50 centimeters drop. I give these results only to show the small variation in results on the same materials. In rocks of low toughness there is generally no variation.

Several series of cement briquettes, of the same size as the rock cylinders, have been broken in this machine, with practically no variation in the results. It was necessary in these tests to use a $\frac{1}{2}$-kilogram hammer to give high numerical values to the results. This test has also been found most useful in grading asphalt surface mixtures. Some interesting penetration tests have also been made on wood paving blocks.

In concluding I may state that a very interesting series of tests are at present being made to determine the detonating points of the high explosives. It has already been ascertained that more energy of blow is required to detonate nitro-glycerine than a number of the other high explosives. It is very easy with this machine to determine the detonating point of an explosive at a given temperature within 1 centimeter fall of the hammer. Nitro-gylcerine, for instance, detonates at a 30 cm. drop at 29°, 31 cm. at 28°, 34 cm. at 24°, 35 cm. at 23°, 67 cm. at 11°, and 95 cm. at 8°.

AN INSTRUMENT FOR MEASURING DEFORMATION OF MATERIALS.

By H. F. Moore.

In 1903, Messrs. Adams and Hahn, while studying reinforced concrete beams in the Materials Laboratory of the University of Wisconsin, found it necessary to devise an apparatus for the measurement of actual elongation and compressions along the longitudinal fibers of beams. Measurements to one one-thousandth of an inch were required and several measurements were to be taken as nearly simultaneously as possible over horizontal distances, so that the micrometer principle was not convenient.

A method was tried in which deformation was measured by the motion of a pointer over a dial, a drum 1 in. in circumference being on the same axle as the pointer, and the drum being rotated by a silk thread passing over it. This method was not successful owing to the great change in reading of dial caused by a slight change of moisture in the air near the silk thread. The idea was then suggested that the silk thread be replaced by a fine silk covered copper wire, the silk giving a firm frictional hold and the copper core giving constancy of length to the wire. This idea was successful, and the apparatus devised by the experimenters is still in use for making determinations of the position of neutral axis beams.

An instrument based on the same idea, but applicable to a wider range of tests, has been in successful use at the Materials Laboratory of the University of Wisconsin for a little over a year. The essential part of the apparatus is shown in Fig. 1. The drum D and the pointer P are fastened to an axle revolving in hardened steel bearings B. Over and around the drum passes a fine insulated copper wire (No. 36 being the usual size). The drum being one inch in circumference and the dial L being divided into one thousand parts, readings can be made to one one-thousandth of an inch on the limb, while by means of a vernier V readings to one ten-thousandth of an inch are possible. The moving parts are very carefully balanced. The whole apparatus can be fastened to

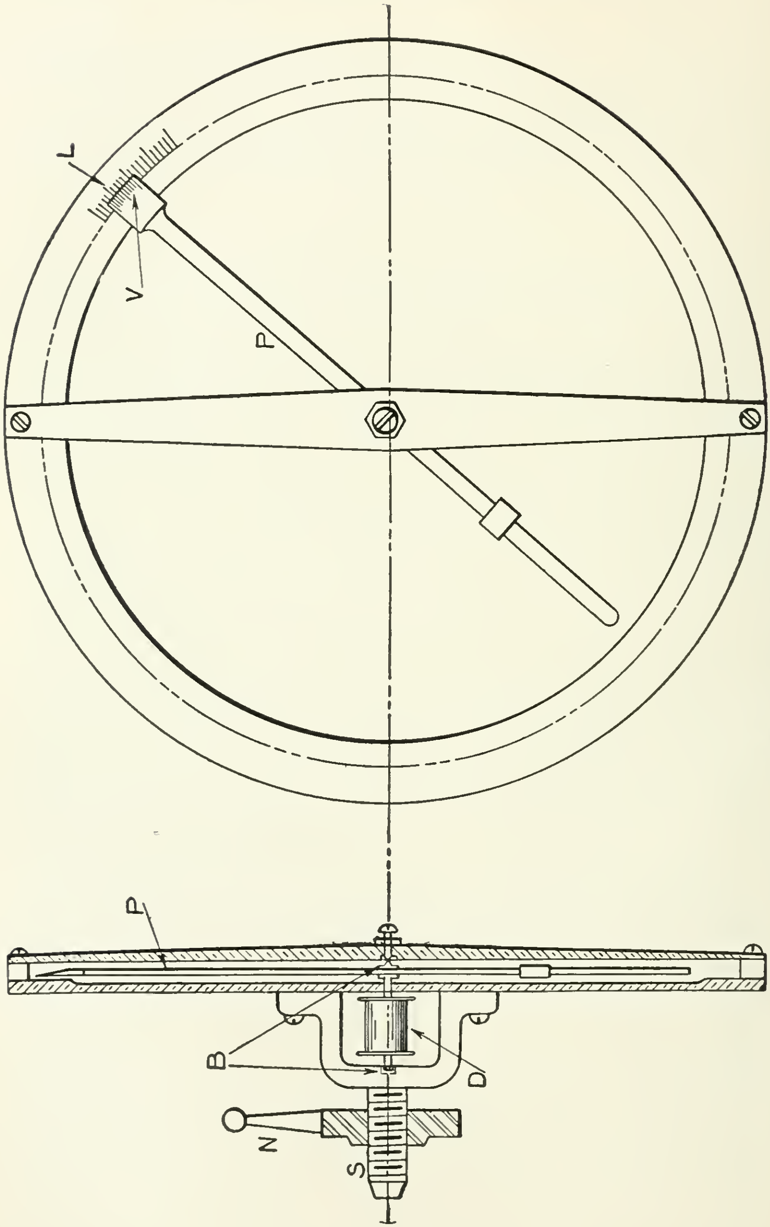

FIG. 1.—General Arrangement of Apparatus.

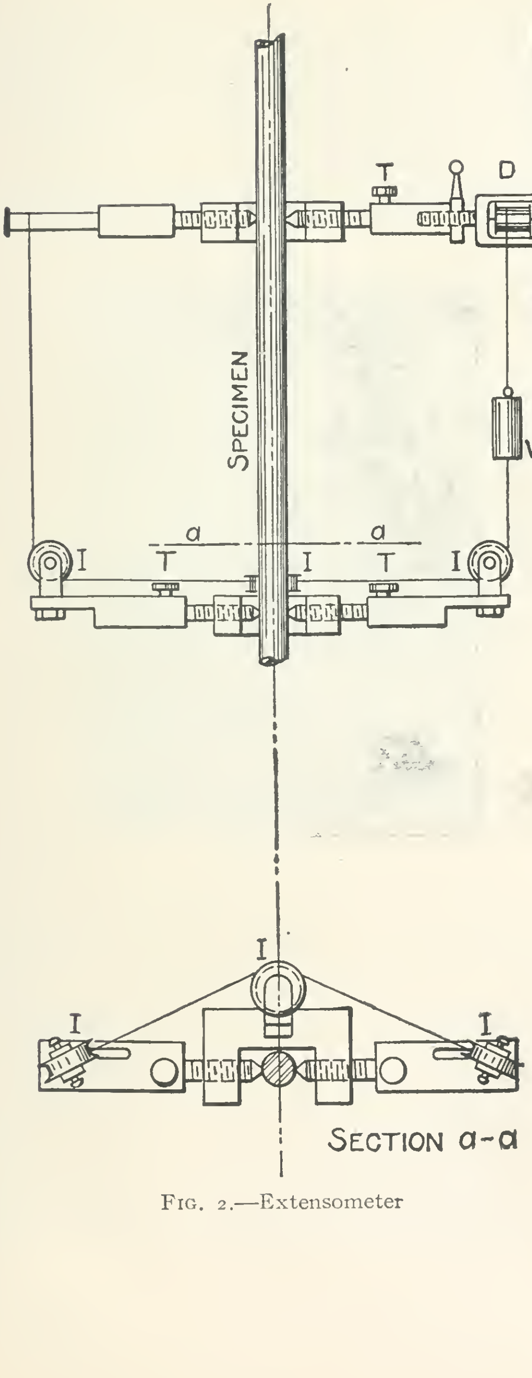

FIG. 2.—Extensometer

clamps or surfaces by means of a screw S which allows some axial adjustment of the whole apparatus, and the dial can be clamped in any position by means of the lock nut N. In attaching or removing the apparatus no disturbance of the adjustment of the axle in its bearings is necessary.

Fig. 2 shows the apparatus used as an extensometer, the form of clamp shown being especially designed for attachment to exposed rods in reinforced concrete beams. The dial is screwed into a block which in turn is attached to a pointed screw, the clamps being fastened to the specimen at two diametrically opposite points by means of two pointed screws. The fine copper wire is kept taut by the weight W, and passes around the drum D, then down to lower clamp and over idler pulleys I, I, and I, and up again to the upper clamp. The outside idler pulleys are adjustable as to distance from specimen and as to angle through which they may be turned about a vertical axis. The axles of the outside idler pulleys can be kept horizontal when screws are turned by loosening the thumbscrews

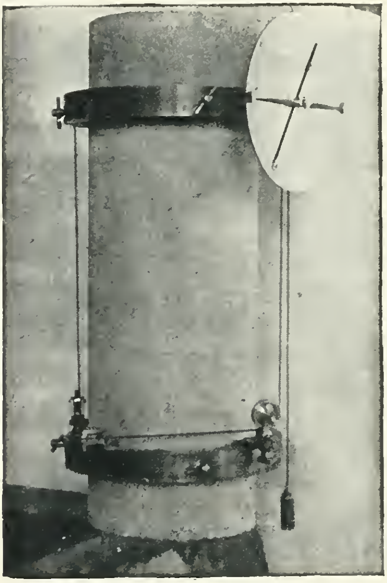

FIG. 3.—Compressometer.

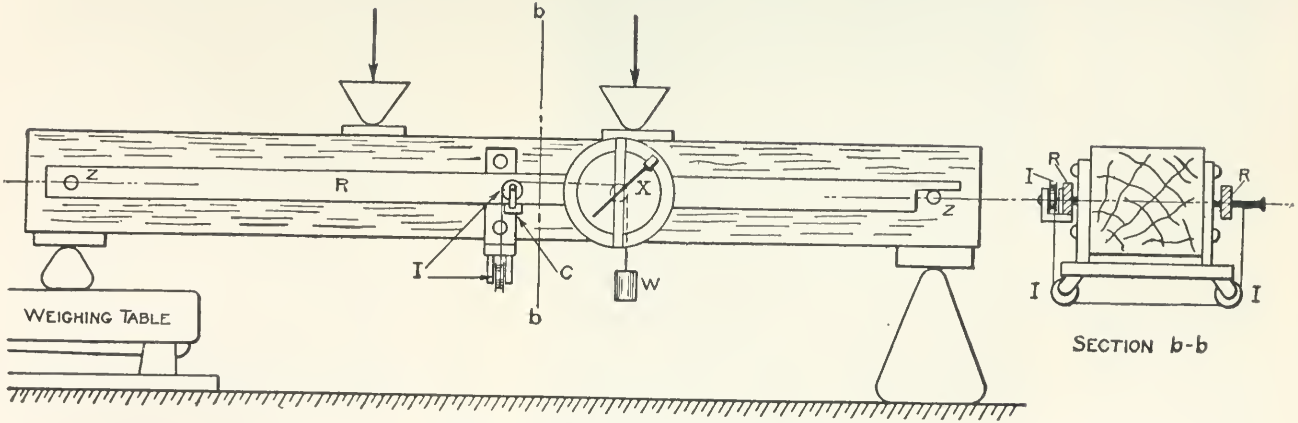

FIG. 4.—Measurement of Deflection.

TT and turning the blocks. All axles run in hardened steel bearings. The apparatus reads twice the average elongation of the specimen. In this form the apparatus has been used to determine the modulus of elasticity of steel and to measure the elongation of exposed reinforcing rods in concrete-steel beams.

Fig. 3 is from a photograph of the apparatus used as a compressometer attached to a 6 in. concrete cylinder. Circular clamps with three pointed screws in each are attached to the cylinder at any given distance apart and the fine copper wire brought from one side of upper to lower clamp, round these idler pulleys to other side of cylinder and then up to drum of dial apparatus, which is fastened to the upper clamp, round the drum and finally to the weight which keeps wire taut. As in the extensometer, the dial shows twice the average deformation. In this form the apparatus has been used to measure the compression of concrete and of timber.

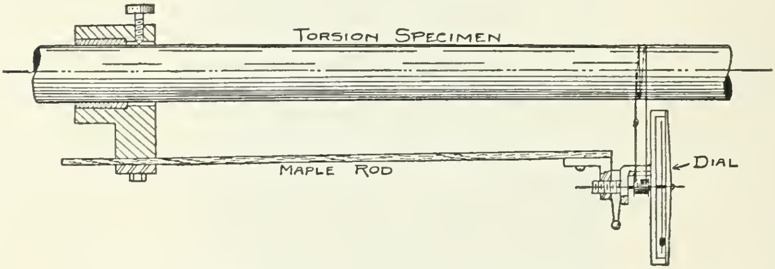

FIG. 5.—Measurement of Torsional Deformation.

Fig. 4 shows the adaptation of the dial to measuring deflection in a cross bending test, a stick of timber being shown as the specimen. On each side of the specimen are pins ZZ, these being attached at the neutral axis. Side pieces RR are attached to the beam by two of these pins at one end and rest on the other two pins at the other end, thus permitting sliding at one end. To the center of the beam or at any other point where it is desired to measure deflection is attached a clamp C, carrying idler pulleys I and I. From a pin attached to the right hand side piece (see cross section through b) extends the fine copper wire down to the clamp, over the idlers I and I, and up to the left hand side piece where it passes round a third pulley, and thence around the drum of the dial apparatus, which may be screwed at any convenient position on the left hand side piece. As in the other cases, the wire is kept taut by a weight W, and the dial reads twice the deflection. As shown in Fig. 4, the apparatus has been used to measure the deflection of timber and of concrete beams. A smaller framework made of metal has been used in measuring the modulus of elasticity of steel, in a cross bending test of bars $\frac{3}{4}$ x 1 in. over a 12 in. span, giving results for the modulus of elasticity practically identical with those of tension tests.

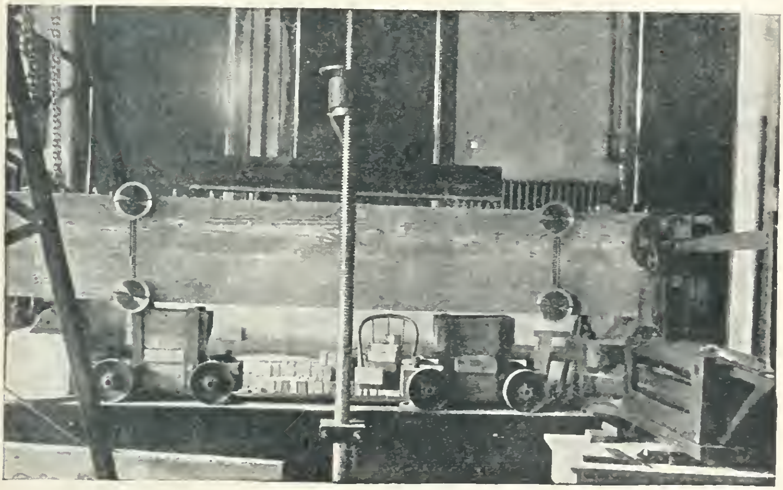

FIG. 6.

Fig. 5 shows the arrangement for measuring torsional deformation. At one end of the gauged length of the specimen is a clamp, and to this clamp is fastened a maple rod extending parallel to the specimen. The dial is fastened to an angle plate on the free end of this maple rod. The fine copper wire wrapped round drum and specimen acts as a belt and is kept taut by the constant pressure of the maple rod acting as a spring. The motion of the pointer over the dial indicates actual detrusion at surface of specimen over the length covered between clamp and wire. This form of the apparatus has given good service in measuring the shearing modulus of elasticity of steel shafts.

The adaptability of the dial to special cases of measuring deformation is one of the strongest points of the apparatus. It has been used at Wisconsin to measure deformation in the web of a built up steel I beam, to measure the deflection in a small cast iron punch frame, as before noted, to make determinations of the posi-

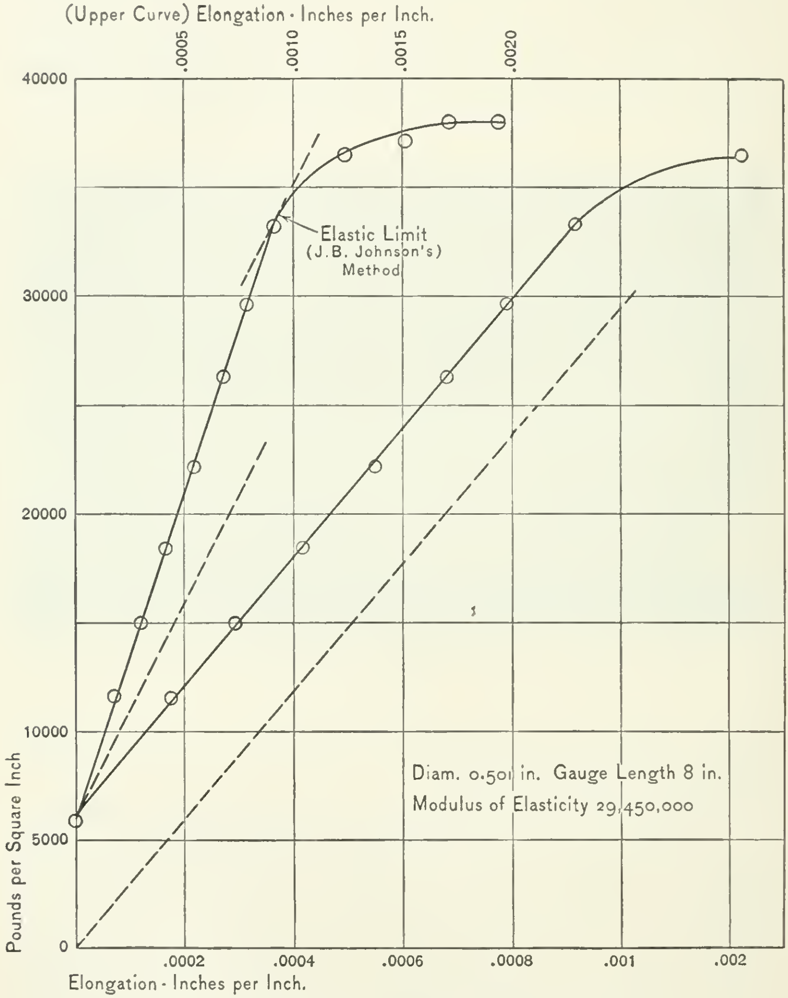

FIG. 7.—Tensile Test of Wrought Iron Specimen.

tion of the neutral axis in concrete and in timber beams, and to measure vertical deformation in the stirrups of reinforced concrete beams, this last use being illustrated in Fig. 6. One of these dials is used to measure the extension in a standard test bar used for calibrating the testing machines in the laboratory.

The dials are calibrated for different sizes of wire by fastening to a lathe carriage with the attached wire fastened to the tail stock. The carriage is then moved a known distance, usually ten inches, as shown by a standard scale, and the motion as shown by the dial noted. A test was made on one dial to determine tendency of wire to slip over drum. The dial was fastened in the tool post of a lathe and the wire looped round a small pin placed eccentrically in the lathe chuck. The wire led from pin to dial, was wound $1\frac{1}{4}$ times around dial and kept taut by a weight. The lathe was turned slowly by hand and maximum and minimum readings of dial noted before and after a run of 100 revolutions. It was found that the surface of the drum could be given a vibratory motion of 0.143 in. at a speed of 120 times per minute before slipping occurred and that then it was due apparantly to stretching of the wire. It was found that bare wire apparently was as good as insulated wire in this respect. This is a much severer test than has ever come on the dial in any static test to which it has been subjected.

Fig. 7 shows the results of a tensile test on a wrought iron test piece 0.501 inch in diameter and with an 8-inch gauge length, the centers of the circles indicating the points as computed from the observations. This curve is submitted here as it is considered a fairly good test of an extensometer to get data for a stress-deformation curve of iron or steel within the elastic limit.

The dials in use at Wisconsin have all been built in the shop of the mechanician of the College of Engineering, Mr. E. H. J. Lorenz, and the satisfactory results obtained are due in no small degree to the excellent workmanship of the parts.

The advantages of this apparatus are that it is self-indicating, that no handling of parts is necessary during a test, that the fine copper wires make a very convenient connection between different parts of a specimen and that the apparatus is adaptable to a wide range of tests.

WHITE-SOUTHER ENDURANCE-TEST SPECIMEN.

By Henry Souther.

For certain classes of work, I believe that an endurance test is the best measure of the value of any given material for any given purpose.

Back in the days when the bicycle was most popular this test was forced upon me, and I rigged up in my laboratory many forms of endurance test. I not only used test specimens as such, but I tested by endurance methods many structures, as, for example, assembled wheels, assembled bicycle frames and forks, and bicycle cranks. All of these tests answered the problems for which they were contrived with the greatest finality. I did not hesitate to make recommendations based upon the results obtained; they were conclusive.

The one possible exception to this statement refers to the endurance-testing machine for test specimens. I took for my model the kind of machine used at the Watertown Arsenal, with which I was familiar. Much experience had been gained with that machine, and a great many results were available in the government records; so I hoped it would answer every purpose. The results obtained with it were not as consistent as they should have been, although, as I have already stated, much good work was done and definite results obtained, upon which to base recommendations.

Mechanical difficulties developed with it, due to its construction. The construction consisted of what amounts to a lathe bed with head and tail stocks 33 in. apart, and provided with universal joints, so as to permit the bending of the specimen, the load being applied at the middle supported upon some form of bearing, either roller or plain journal.

The specimen was objectionable, it being very difficult and expensive to make so long a one and get it exactly right. Owing to its length, it vibrated to a greater or less degree, the vibration differing in different tests put upon the specimen different and immeasurable stresses. Also, at the point of application of the

TABLE I. STEELS.

Sample.	C.	P. Per cent.	Mn. Per cent.	S. Per cent.	Si. Per cent.	Ni. Per cent.	Cr. Per cent.	V. Per cent.	E. L. Sq. in. Lbs.	M. S. Sq. in. lbs.	Red. of Area. Per cent.	Elong. in 2 in. Per cent.	Load.	Fiber Stress.	Endurance.		Remarks.
															End No. 1.	End No. 2.	
27194	.40	.037	.63	.033	....	....	....	...	59,800	81,200	51.8	30.5	155	53,600	19,300	Jumped and bent	Natural condition.
27195	.47	.049	1.14	.043	....	....	....	...	75,900	113,400	56.3	28.5	"	"	156,600	Taken out.	do.
27817	.25	.008	.59	.007	....	3.49	....	...	55,400	79,800	61.8	29.5	"	"	33,500	75,400	do.
27818	.30	.059	.62	.012	....	3.63	....	...	61,300	90,800	46.8	23.5	'	"	165,000	435,000	do.
28153	.35	.013	1.82	Trace	.609	2.02	....	...	....	176,800	35.0	11.5	"	"	108,301,900	108,301,900	Annealed at 1150° F. Did not break.
28154	.33	.014	1.66	.002	.766	....	....	...	157,200	178,200	32.9	12.5	"	"	615,100	636,600	Natural condition.
28155	.287	.035	.62	.027	....	.722	....	...	111,400	140,400	57.5	20.0	'	"	100,000,000	100,000,000	do. did not break.
28993	.267	.043	.41	.063	....	1.75	1.02	...	76,500	104,000	50.5	21.5	"	"	65,100	76,500	do.
29042	.385	.017	.40	.019	....	1.18	1.17	...	66,300	89,300	66.8	29.0	"	"	3,900	4,200	do. both ends bent.
29042	.385	.017	.40	.019	....	1.18	1.17	...	84,600	109,200	57.4	18.5	"	"	609,300	1,492,800	Quenched at 1500° F. Annealed at 1050° F.
29044	.894	.015	.31	Trace	....	....	....	...	77,500	135,700	21.8	8.0	"	"	70,500	135,700	Natural.
29044	.894	.015	.31	Trace	....	....	....	...	70,300	131,800	18.4	6.0	"	"	56,100	17,000,000	Quenched at 1500° F. Annealed at 1050° F.
30500	.656	.013	.39	.029	....	....	....	...	53,800	84,200	57.4	28.0	"	"	23,000	27,500	As received (Krupp).
30500	.656	.013	.39	.029	....	....	....	...	81,700	155,300	51.0	19.0	"	"	89,700	188,700	Quenched at 1500° F. Annealed at 1050° F.
30501	.405	.035	1.05	.027	.160	....	....	...	95,300	113,500	58.8	21.0	"	"	168,500	416,400	As received (Krupp).
30501	.405	.035	1.05	.027	.160	....	....	...	129,500	143,500	52.3	16.0	"	"	147,700	205,700	Quenched at 1500° F. Annealed at 1050° F.
30502	.313	.083	1.04	.039	.450	.57	.92	...	92,900	115,300	55.1	22.0	"	"	1,040,100	11,044,000	As received (Krupp).
30502	.313	.083	1.04	.039	.450	.57	92	...	143,900	157.800	44.4	15.0	"	"	4,755,900	Taken out	Quenched at 1500° F. Annealed at 1050° F.

TABLE II. MANGANESE BRONZE.

Sample.	Cu.	Sn.	Pb.	Fe.	Zn.	Red. of Area.	Elong. in 2 in.	Sample.	E. L. Sq. in.	M. S. Sq. in.	Load.	Fiber Stress.	Endurance.	
													No. 1 End.	No. 2 End.
36830 Government Standard Casting Bronze.......	59.47	0.71	0.18	1.60	38.04	25.1	26.0	36830	46,200	80,600	35	12,350	1,793,000	1,793,000
											75	26,500	1,220,100	1,904,300 Broke
36831 Rolled Rod.......	....	0.71	....	....	....	23.6	22.5	36831	55,200	72,500	35	12,350	1,572,100	1,572,100
											75	26,500	9,993,500	12,153,800 No. 1 Broke
											100	35,300	....	3,710,800 No. 2 "
36832 Rivet Stock	....	0.71	....	....	....	65.1	42.0	36832	38,500	64,100	75	26,500	10,078,700	10,078,700
											100	35,300	536,400	1,011,800 Broke

load, more or less heat developed and to a greater or less extent must have influenced the test, because the heating came at the point of greatest bending moment. High speeds with this form of specimen were out of the question, because of the vibration, and something like five or six hundred r. p. m. seemed to be the upper limit. All this criticism is not with the idea of detracting from the value of the work done at Watertown, because I believe it has been very valuable, but simply to show my starting point in the evolution of an endurance machine.

With all these facts in mind, Mr. Maunsel White and myself devised a test specimen which seems to do away with all the objections mentioned without introducing others of serious moment.

This specimen, measuring about 13 in. over all, is a comparatively cheap one to prepare; also, as it is large at its center, there is little trouble in the lathe due to bending. It is, therefore, quite easy to make accurate to size and straight. It is a double-ended specimen, which makes it possible to obtain definite results, even though there may be a flaw or other defect in one end. This double-ended specimen also gives check results in case both ends are sound. I feel that the higher of the two results is the proper one to accept, inasmuch as it is the highest measure of the efficiency of the material under test, and no material can endure beyond its capacity.

The specimen is supported at the center portion on large ball bearings, and may be rotated at very high speeds. No heat is produced, at least no great amount of heat, and, even if it were, the center portion being larger than the ends, it would matter little. There is no wear of any kind on the specimen, the loads being applied at the ends, therefore, not at the point of greatest bending moment. The critical points of the specimen are, of course, the fillets, coming at the point of greatest bending moment. These must be accurate to shape and perfectly machined; slight flaws or defects at this point are serious.

At the best, an endurance test must be a comparative one, and it is for this reason that I am bringing this matter before the Society at this time. We must get a standard endurance specimen as soon as possible, and I put this one, devised by Mr. White and myself, before the Society as a basis upon which to start the discussion. I ask the Society to take some action, and perhaps appoint a committee which shall consider the whole question of a standard endurance-test specimen. It is more important, to my mind, than any other test specimen that has been standardized by the Society. Another suggestion I wish to make in connection with endurance tests is that as far as possible (consistent with shop secrets) this Society act as a clearing house for any endurance results that may be obtained upon any form of standard specimen adopted by it. I cannot help feeling that there are many results that could be reported to the Society with this idea in view without commercial injury to those reporting them. If my assumption is correct, surely the benefit resulting from such action would be invaluable.

I append herewith a table of characteristic results obtained without going into exact details. This series of tests was undertaken to get a ground work for suitable comparison. For example, the first specimen may be classed as high grade machine steel. It will be noted that the elastic limit was about 60,000 lbs. per sq. in., as shown by the tensile test. My idea was to break this quickly, and I therefore loaded it with a fiber stress of 53,600 lbs. per sq. in. and quick results were obtained, as expected. I then went forward with high grade material, one after another, variously treated, the heating being carefully done in an electric furnace in connection with a pyrometer. There are some exceptions to this, in that some of the specimens were tested as received.

The results obtained show the tremendous possibility in the use and adoption of high grade materials. The tests also show that in order that the endurance test may not be too prolonged and therefore not practical, it must be conducted in such a way as to give quicker results than some of those given. For example, it is practically out of the question for a manufacturer to wait for a machine to run one hundred million revolutions, or probably ten weeks, running night and day at 1,300 r. p. m. Consequently, I have adopted lately an increasing fiber stress; for example, starting the test at 50,000 lbs. fiber stress, and, if the specimen endures for ten million revolutions, increase it to 60,000 lbs., and after the next ten million increase it to 70,000 lbs., and so on until rupture occurs.

It is still possible to compare the behavior of various steels and to show the results graphically. The test is, consequently, more useful because more valuable.

A higher number of revolutions than adopted for our tests may be used with this machine, if considered desirable, but I feel that 1,300 r. p. m., more or less, is a practical number. For example, the crank shaft of an automobile rotates at that speed, and there are many rotating parts in the manufacturing industries that are near that speed. Were a very much higher number to be adopted certain unknown elements might be introduced into the test that would render the results questionable, as being a test carried on under abnormal conditions.

The number of revolutions in a given time is shown in the following table.

1,300	revolutions	per	minute,
78,000	"	"	hour,
1,862,000	"	"	day,
13,034,000	"	"	week,
55,860,000	"	"	month.

TABLE III. ALUMINUM.

Sample.	Mn.	Cu.	Zn.	Al.	Spec. Grav.	M. S. sq. in.	Fiber Stress.	Endurance		
								No. 1.	No. 2.	
37261	0.11	7.84	0.00	92.05	2.86	*16,000	10,600	558,600	816,500	Broke
37262	Trace	0.34	16.24	83.42	2.97	*25,000	"	1,550,400	1,618,300	"
36152	......	3.20	26.72	70.08	3.23	32,000	"	1,613,900	477,600	"
36155	......	6.80	22.78	70.42	3.22	....	"	3,438,400	435,500	"
36156	......	8.20	22.44	69.36	3.24	20,000	"	12,038,500	815,600	"
37044	......	3.00	27.00	70.00	3.30	*30,000	"	5,415,900	257,300	"
37045	......	.....	27.00	......	.....	....	"	3,029,900	543,000	"
37046	......	.....	27.00	......	.....	....	"	2,513,300	707,200	"

* Estimated from other specimens.

For any manufacturer whose product goes into machinery subjected to dynamic loads, such a test ought to be extremely valuable. Further, the heat treatment of steel and the great benefits derived from it are rapidly being appreciated and increasingly used by all manufacturers. Such a test is a measure of the benefit due to heat treatment. Moreover, I have found that certain clients in talking about the increased strength of new alloys and heat treating in general, have said—"Oh! yes; of course there is a great increase in strength and apparent toughness and good qualities in general, but how about the capacity of the metals in such a condition to resist shock?" I believe that this test does show the capacity of metals to resist shock, whether of impact nature or alternate stress.

In the table of results given will be found a number of aluminum and bronze specimens which are very instructive.

We are just beginning to get at the results of tests on Vanadium steels. The few we have that are trustworthy show a considerable benefit under the endurance test, but I do not like to put them on record, for there are certain features of the treatment unknown to me. We also had the misfortune to have our pyrometer go wrong in connection with the treatment of several specimens, and the results are, therefore, worthless. To generalize, however, it is my impression that Vanadium will add to the endurance of any given steel if present in quantities approximating 0.25 per cent.

The increased endurance seems to be at least four to one, but in view of the above lack of knowledge on my part as to all the conditions, I do not wish to commit myself fully. In another year it ought to be possible to put definite figures before the Society.

DISCUSSION.

MR. WILLIAM K. HATT.—The author made the statement, I think, that in his opinion defects of brittleness brought out by the impact test proper are also shown in this endurance test. Am I right? If I am right, I wonder what evidence there is for that opinion. **Mr. Hatt.**

MR. HENRY SOUTHER.—The answer takes me back to bicycle days. We tempered a great deal of nickel steel tubing and it was subject to shock in use. Those tubes which stood up well in the endurance machine gave us no trouble in actual practice. The same rule seems to be developing in the automobile business. The business is too young to speak definitely, but it is apparent already that it is in some measure true. **Mr. Souther.**

MR. EDGAR MARBURG.—Mr. Chairman, in reply to one or two suggestions or recommendations that Mr. Souther offered, the first being the question of the standard specifications for endurance tests to be taken up by the Society, I should like to say that that comes directly within the province of Committee K on Methods of Testing, of which Professor Lanza is Chairman. And the second, that this Society should be made a clearing-house for reports on endurance tests, even though it may seem at first blush that certain commercial interests may be unfavorably affected thereby, I think we all are beginning to feel that he who does not recognize this Society as the best clearing-house for any information concerning materials that he wishes to promulgate, is behind the times. **Mr. Marburg.**

MR. GAETANO LANZA.—I believe that before long we shall have to prescribe, in many cases, specifications for endurance tests; moreover, I will add that in Committee K we have arranged to have a sub-committee on endurance tests. While this sub-committee has not yet been set to work, nevertheless requests have already been sent by Committee K to the various testing laboratories, asking for a statement of their practice in this regard, the replies to serve as an aid to the sub-committee in its work. **Mr. Lanza.**

MULTIPLYING DIVIDERS FOR LOCATING YIELD POINT.

By J. A. Capp.

The difficulties which are encountered in locating the yield point during tension tests are such that any simple cheap device which can assist in its definite location should be of value.

The use of the dividers ordinarily employed for the purpose requires very close watching on the part of the operator, and there is always a considerable interval during which he is apt to be more or less in doubt whether the point of the dividers has really slipped out of the prick punch mark or not. It seems to be a fact that the uncertainties regarding the location of the yield point generally result in the reporting of values the error in which is on the high side. This can hardly be considered as in favor of the steel maker, even should it result in the acceptance of material which otherwise might not be thought to meet specified requirements, and it certainly is not to the advantage of the designer who uses the quantity called the elastic limit in his calculations.

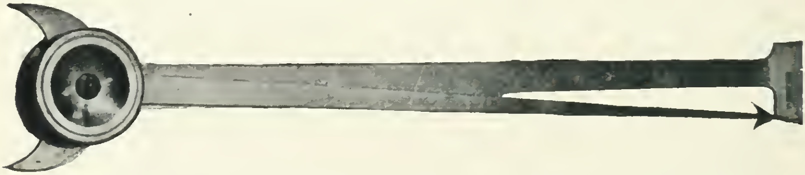

Fig. 1.—Multiplying Dividers for locating yield point on tension test specimens, ½ in. in diam., 2 in. long.

There has been in use in the laboratory with which the writer is connected, a pair of dividers (Fig. 1) made on the same principle as the scaling dividers used largely by architects. The cut shows fairly clearly the general appearance of the tool which is seen to consist of two arms so pivoted that the motion of the points in which the short arms terminate is multiplied about ten times at the scale and pointer forming the ends of the long arm. To prevent lost motion, it is essential that the pin be fitted very accurately into the bearings in the lever arms. The ends of the bearing pin terminate in cupped and milled heads forming easy grips for the thumb and finger. The short arms of the bent levers are so proportioned that the hard steel points in which they terminate shall be 2 inches apart when the pointer rests over the zero mark on the scale.

In use the steel points are inserted in the prick-punch marks on the test specimen and the instrument held fairly tightly against the test piece. The motion of the pointer across the scale is then watched and when the yield point is reached the very sudden and marked increase in rate of travel of the pointer across the scale leaves no uncertainty as to its definite location.

This device has been used in the testing of all sorts of metals, and it has been found useful even for such soft materials as brass and bronze, where there is no really sharply marked yield point or jog in the elastic curve, as in the case of steel.

THE DEVELOPMENT OF THE PENETROMETER AS USED IN THE DETERMINATION OF THE CONSISTENCY OF SEMI-SOLID BITUMENS.

By Clifford Richardson and C. N. Forrest.

In the early days of the asphalt paving industry no means were available or recognized for determining the consistency of the bituminous cementing material which was in use, other than that derived from placing a small piece in the mouth and judging by its resistance to the teeth, after it had attained the normal body temperature, what its consistency might be. This was purely empirical, and there was no way of recording the judgment in figures.

The need of some more definite way of determining and registering the consistency of a bituminous cement was very soon recognized by Mr. H. C. Bowen, of the School of Mines, of Columbia University, who, in 1888, being engaged by the Barber Asphalt Paving Company in control of its work, devised an instrument, built in a crude way of wood, which he denominated a "Penetration Machine." (Fig. 1.) A few years later this was reconstructed in metal and patented, under No. 494,974, April 4, 1893. There was some difference in the readings of the wooden and the metal machines, the two not being built in the same proportions or with the same weight upon the needle.

The principle upon which this penetration machine worked, and upon which all others which have been designed since then have been based, is the measurement of the distance that a cambric needle of definite size will penetrate into a bituminous cement, under a definite weight, during a definite interval of time and at a definite temperature. The Bowen apparatus has been described by its originator in the "School of Mines Quarterly," 1889, 10, 297, and by one of the authors in the "Report of the Operations of the Engineer Department of the District of Columbia," for the fiscal year 1889–90, page 106, and in the "Engineering Record," October 31, 1891. It is also described at length in "The Modern Asphalt Pavement," page 522.

This apparatus served its purpose extremely well for a number of years and does so to-day, to a very large extent, for regulating the consistency of bituminous cements in the laboratory and in paving plants, but it was recognized after some years that the readings were purely arbitrary and that if the original machine was destroyed there would be no way of replacing it. This fact was recognized by Mr. A. W. Dow, the successor of one of the authors of this paper in the office of the Inspector of Asphalt and Cements, at Washington, D. C., and in his report for the fiscal year ending June 30, 1898, he proposes the use of a needle, fixed in the end of a rod, the weight of which can be varied. The rod is held in a vertical position by means of a jaw clamp which, when released, admits of the penetration of the needle, under direct weight, with practically no friction, into the surface of the bituminous cement to be tested. This proposition was a distinct advance over the indefinite arrangements of the Bowen apparatus. It was

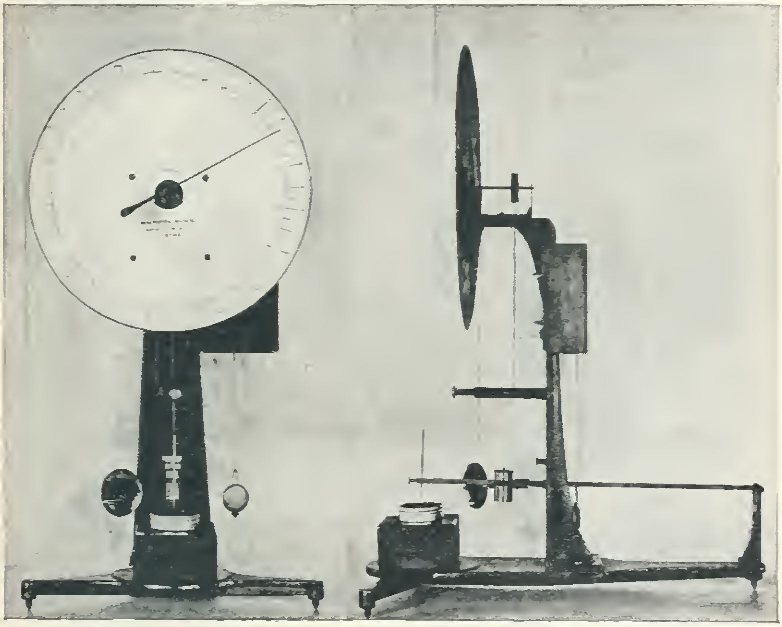

Fig. 1.

afterwards worked out in greater detail by Mr. Dow, and was described by him in the "Report of the Operations of the Engineer Department of the District of Columbia," for the fiscal year ending June 30, 1901, page 158, and in a paper read by him before the Society in 1903 (Vol. III, p. 354). The construction of the apparatus is illustrated diagrammatically in both places. See also Fig. 2. The arrangement is such that a No. 2 cambric needle, weighted with 50, 100 or 200 grams, depending upon the temperature at which the consistency of the bituminous cement is to be determined, is allowed to penetrate for five seconds into the material the consistency of which it is desired to determine. The depth to which the needle penetrates is registered in tenths of a millimeter by a device which is quite independent of the needle itself. It is readily seen that this instrument is one which is based upon certain definite conditions which can be reproduced at any time. It has been in use satisfactorily for a number of years, but possesses certain disadvantages which an effort has been made to overcome in the "Penetromoter," which we are about to describe.

In the Dow instrument all the parts are of very light construction and require a certain delicacy of touch to use it satisfactorily and, consequently, it is not easily manipulated by such men as are found at paving plants, although these disadvantages are of slight consideration in the laboratory. The shelf upon which the sample to be tested is placed is fixed and the needle must, therefore, be brought down toward the surface of the bituminous cement until it is in contact with it. On each side of the shelf which holds the sample are the two rods of the frame from which the weight which acts upon the needle is suspended. These are much in the way in adjusting the needle in contact with the surface of the bituminous cement and restrict the size of the sample of the latter.

In the "Penetrometer", Fig. 3, an attempt has been made to overcome these features, without seriously impairing the accuracy of the instrument. The sample to be tested, which may, if desired, be of large or small size, is placed upon a table which is supported upon a screw, enabling the needle to be set at zero, and the sample to be brought up to contact with the point by elevating it with the screw. The entire weight acting upon the needle is contained in the tube which holds it and, being placed at the lowest possible point in the tube, does not tend to seriously divert it from the vertical on the release of the clamp and makes it possible to do away with the frame which is so much in the way in the Dow apparatus. The "Penetrometer" is given greater stability than the Dow apparatus by making a much larger and firmer clamp to hold the tube, while all the other parts of the instrument are rigidly constructed. The increased friction of the clamp on the rod reduces the extent of the penetration of the needle by one- or two-tenths of a millimeter, but this is practically of no consequence, as it is a variation not greater than that due to different needles or to the personal equation of various operators.

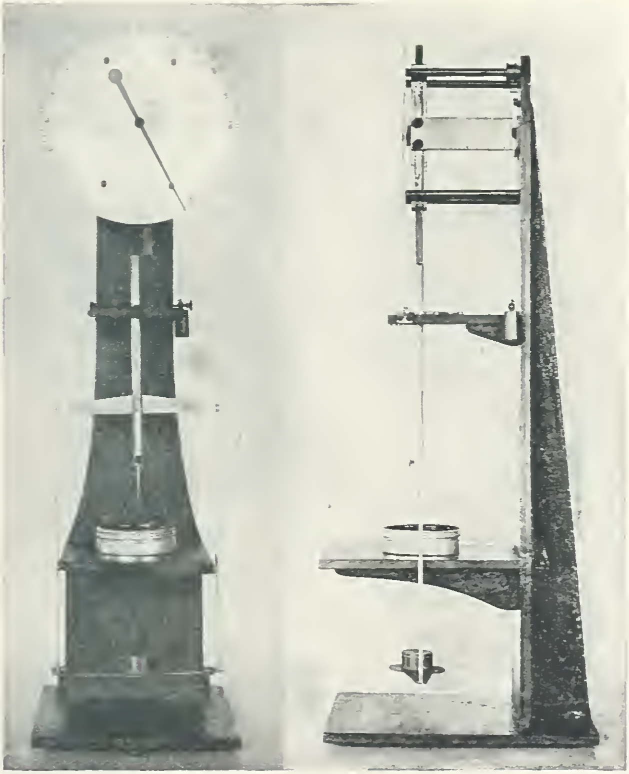

Fig. 2.

The determination of the depth to which the needle has penetrated is arrived at by a similar means to that employed in the Dow machine, a rack and pinion, but the rod to which the rack is attached is prevented from moving, not by a balance weight attached to a cord as in the Dow machine, but by a spring exerting a slight pressure against its side. This does away with the opportunity for the cord and balance weight to be knocked out of place or lost and makes the apparatus much more convenient to move from place to place. The penetration of the needle is registered in tenths of millimeters, on the same scale as in the Dow machine, and the time during which the weight acts is made five seconds instead of one, as is the case with the Bowen apparatus.

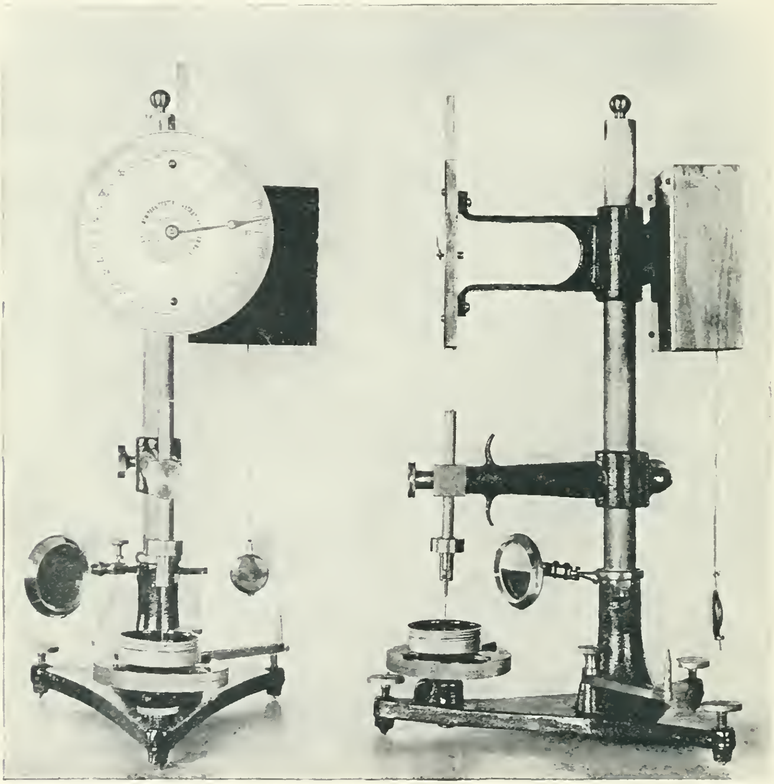

Fig. 3.

The detail of the manipulation of tests is the same with the "Penetrometer" as with the Dow apparatus, and, owing to the manner in which this has been described in a number of places, it is unnecessary to repeat the directions here.

The "Penetrometer" is manufactured by Messrs. Howard & Morse, 1197 DeKalb Avenue, Brooklyn, N. Y.

DISCUSSION

Mr. Whinery.

Mr. S. Whinery.—The apparatus designed by the authors and described in this paper is obviously a distinct advance over the penetration devices that have preceded it.

While penetration apparatus of this general design has undoubtedly served a useful purpose for determining approximately the relative hardness of paving cements, they are so wrong in principle and so defective in practical operation that they must be considered as having very little claim to recognition as accurate scientific or practical apparatus. Some of their defects may be briefly pointed out:

1. The needle used is a pointed spindle. As this spindle penetrates the bitumen, it displaces a volume of bitumen equal to the volume of the immersed needle, and the work done by the weight actuating the needle is proportional to the volume thus displaced. This volume increases as the square of the diameter of the needle. Consequently the rate of penetration for successive equal periods of time must constantly decrease as the depth of penetration of the needle increases. The depth of penetration of the needle in a given time is therefore not a correct measure of the hardness of the bitumen. The results would be more correct and satisfactory if the seconds of time required to attain a certain fixed depth of penetration were made the standard of comparison.

2. Since in pitch and similar substances the ordinary laws of friction do not hold good, the frictional adhesion of the paving cement to the surface of the penetrating needle is not independent of the area of that surface. It is rather a direct function of the area of surface in contact. The frictional adhesion between the needle and the bitumen under penetration increases more rapidly than the depth of penetration and this varying element of resistance is in itself of sufficient magnitude to discredit the constant rate of penetration assumed in the use of these devices.

3. In these devices there is no provision for determining accurately the period of time during which the penetration takes place. The needle is released at the beginning and clamped fast

at the close of the operation by the hand of the operator, and the **Mr. Whinery.** period of time is determined by observing the beats of a pendulum. Where the period of time used is one second the percentage of possible error in the time observation and in the manual releasing and clamping of the needle is likely, if not almost certain, to be so great as to make the observations inaccurate.

4. There is necessarily some friction between the shaft or stem carrying the needle and the guide-bearings through which it passes. The resistance to the free movement of the needle caused by this friction may vary considerably with the differing degrees of pressure between the needle shaft and the guides, which must be unavoidable in operating the device, and this may affect the accuracy of the results obtained.

5. As remarked by the authors, there is more or less difficulty in setting the delicately pointed needle in a uniform position of contact with the surface of the bitumens to be tested. It is also true that so delicate a needle, requiring a very slight weight to actuate it is peculiarly likely to have its free movement interfered with by the small particles of inorganic matter present in some bitumens, since the ratio between the resistance offered by these particles and the actuating weight is small.

6. The registering device used to record the depth of penetration is unsatisfactory and may be inaccurate. A slight difference in the pitch of the cord as it is wound around the index shaft may change materially the index reading, and possible slippage of the cord on the index shaft may make the readings unreliable.

These defects not only exist in theory, but they have been confirmed by careful observation. The writer and his chemical assistant, Mr. F. C. Wallace, made a careful study, about ten years since, of this and many other devices intended to determine the hardness of bitumens. Needle penetrators of great delicacy and accuracy were used. The releasing and stopping of the needle was effected by an electro-magnetic clamp, the current actuating the magnet being closed and opened automatically by the second hand of a clock. Special provision was made for eliminating friction, and the penetration was measured by a micrometer reading to one one-thousandth of an inch. The conclusion reached was that needles of spindle or conical form do not give results accurately comparable between two paving cements differing in hardness.

Mr. Whinery. The writer believes that in these and all similar penetration devices the pointed spindle needle should be replaced by a needle with a spherical or hemispherical head, the shank above the head being reduced in diameter so that there will be no frictional contact except upon the head itself. Needles of this form were found in the studies referred to above to give much more satisfactory results than the pointed spindle needle. The theoretical reasons for this are obvious from what has preceded.

While a penetrometer designed for rapid approximate determinations in the laboratory or works need not give results of great accuracy, it should, if possible, be designed upon correct principles, so that its errors may be due alone to lack of sensitiveness or to necessarily hasty observations, and not to inherent defects in the principle of its operation. Penetrometers of the class described in the paper do not, we have seen, fulfil this requirement, and it is very desirable that something which shall comply more closely with correct scientific principle should be devised.

The writer has recently given a good deal of attention to this matter and has designed and constructed a penetrometer which seems to more nearly fulfil the required conditions, but the apparatus has not yet been fully enough tested to speak confidently of results.

In this apparatus a needle with a hemispherical head and reduced shank is used. But its principal difference from the class of penetrometers described by the authors consists in the substitution of the impact of a falling weight for the continued action of a weight acting through a period of time. In use the needle is pressed into the sample to be tested until the upper plane of its hemispherical head coincides with the surface of the sample; the weight is then raised to the fixed height and allowed to fall freely upon the top of the shaft carrying the needle. The blow drives the needle into the sample to a depth proportional to the hardness of the material, and this depth of penetration is read off directly from a linear vernier scale reading to millimeters.

The advantages which this apparatus is expected to develop over the present style of penetrometers may be briefly stated:

1. The form of the needle should insure that the volume of bitumen displaced and the work done in displacing it, shall be in direct ratio to the depth of penetration, and that the adhesional

friction between the bitumen and the needle shall be constant in magnitude throughout the operation. Also the absence of the delicate and sometimes almost invisible point of the needle now used will make it possible to more accurately adjust the needle to the surface of the bitumen to be tested. **Mr. Whinery.**

2. The work done by a weight falling from a fixed distance will be a constant quantity and the depth to which it forces the needle into the bitumen should vary directly with the consistency or degree of hardness of the material to be tested. The relative value and effect of any friction in the working parts of the apparatus will be greatly lessened.

3. By the use of the impact of the falling weight the penetration will be accomplished almost instantaneously. The time element and the manual releasing and clamping of the needle, with all their attendant possibilities of erroneous observation, will therefore be entirely eliminated. The personal equation of the operator in manipulating the apparatus will also be eliminated.

4. The penetration will be read directly from a linear vernier scale, and not through the intervention of a thread wound over an index shaft, and the record should be more accurate accordingly.

The writer may be able at some later date to present to the Society a more complete description of this apparatus and the results of practical tests made with it.

Mr. Richardson and Mr. Forrest. MR. C. RICHARDSON and MR. C. N. FORREST.—If the penetrometer which has been described is to be regarded as an instrument of precision for the determination of the internal friction of bituminous cements in precise terms it is, of course, open to the criticism which Mr. Whinery had directed against it. This, however, is not the object of the instrument. It is intended only as a convenient means of determining, in laboratories where control is exercised over bituminous cements and at plants where they are in use, with some degree of uniformity and accuracy, whether they are of the proper consistency or that which has been specified and recording the consistency in figures. The true viscosity is not the matter at issue but whether the person who prepares such cements is doing so in a regular manner. The ease and rapidity with which a large number of such determinations can be carried out and the possibility of its satisfactory use by

Mr. Richardson and Mr. Forrest. plant foremen is the object in view. In our laboratory, where a very large number of cements may be received and examined in a day, the mere question as to whether the weight should act upon the needle for one or five seconds is worthy of consideration as a matter of time alone although this period of time is now the standard in connection with the use of the penetrometer. While an instrument of the type proposed by Mr. Whinery would be of interest as a standard it could not find practical application, in our opinion, in the plant or in the busy laboratory engaged in controlling the work of a large corporation constructing five or more millions of square yards of pavement a year.

The penetrometer which we have described is designed for such a purpose but we shall welcome the form proposed by Mr. Whinery if it will permit of rapid work and its use by unskilled persons.

The Chairman. THE CHAIRMAN (Mr. Mansfield Merriman).—Does considerable penetration indicate good or poor quality?

Mr. Forrest. MR. C. N FORREST.—Neither; certain conditions of construction require soft cement and others a hard cement, depending on the requirements of the work to be done. That is a matter of specification or advance knowledge. The instrument is merely used to keep the consistency or penetration uniform. It is not an instrument of precision—but designed for practical work.

Mr. Church. MR. S. R. CHURCH.—I should like to ask the author, in the case of low temperatures or high temperatures, such as 32° or 100° F., how that temperature is maintained for a sufficient length of time to permit of securing check readings; my understanding being that in most cases several readings are required and then the average of these taken in making up the report; since it is a matter of several minutes, at least, the temperature would naturally drop or rise unless there was some provision made for maintaining it.

Mr. Forrest. MR. FORREST.—That is provided for by placing a small tank on the adjustable table in which ice water for low temperatures, or hot water for higher temperatures may be circulated, or the entire machine may be placed in a refrigerator for use at low temperatures; we also have provision for raising the temperature of a small room to 100° F. or more. It is hard on the operator but facilitates the operation.

MR. S. S. VOORHEES.—Is there no means of maintaining high temperatures for outside heat? **Mr. Voorhees.**

MR. FORREST.—The room temperature can be regulated. We have a small room that is ordinarily kept at 77° F. and we can raise it to 100° F. or slightly more. **Mr. Forrest.**

MR. VOORHEES.—I should like to ask further how much the variation in penetration is from varying temperatures, say a degree. Is it appreciable in the penetration? **Mr. Voorhees.**

MR. FORREST.—With the Bowen penetration machine it is about three-quarters of a degree. With this it would be a little different. I don't know just what it would be. **Mr. Forrest.**

MR. EDGAR MARBURG.—I should like to inquire how closely consecutive observations agree? Are a number of penetrations made and averaged, and how closely do they agree? **Mr. Marburg.**

MR. FORREST.—They should agree very closely. With a penetrometer operating, five seconds, provided you keep the temperature constant, in three or four trials you should not get a greater variation than one or two degrees. Each degree is equal to $\frac{1}{10}$ mm. movement of the needle. An average of three or four trials is made. **Mr. Forrest.**

MR. F. O. BUNNELL.—I should like to ask the author if he has made any test for degrees of penetration on the bitumen cement or binder for briquettes manufactured from pulverized coal. **Mr. Bunnell.**

MR. FORREST.—No, we have not done so specifically, but the instrument would be useful for that purpose. **Mr. Forrest.**

MR. CHURCH.—I should like to ask whether any materials have come under the author's observation where, in order to get correct results, it was necessary to set the needle say $\frac{1}{16}$ of an inch or any distance below the surface, due to a sort of film on the surface of the bitumen which is harder than the portion directly beneath it. **Mr. Church.**

MR. FORREST.—No. In such a condition we resurface the sample; that is, the sample is remelted and stirred to produce a fresh surface. **Mr. Forrest.**

CHARTER

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

To the Honorable the Judges of the Court of Common Pleas No. 2 *in and for the City and County of Philadelphia: of March Term,* 1902, *No.* 2056:

In compliance with the requirements of an Act of the General Assembly of the Commonwealth of Pennsylvania, entitled "An Act to Provide for the Incorporation and Regulation of Certain Corporations," approved the 29th day of April, A.D. one thousand eight hundred and seventy-four, and the supplements thereto, the undersigned, Henry M. Howe, Charles B. Dudley, Edgar Marburg, Robert W. Lesley, Mansfield Merriman, Albert Ladd Colby and William R. Webster, six of whom are citizens of Pennsylvania, having associated themselves together for the purposes hereinafter set forth, and desiring that they may be incorporated according to law, do hereby certify:

1. The name of the proposed corporation is the "AMERICAN SOCIETY FOR TESTING MATERIALS."

2. The corporation is formed for the Promotion of Knowledge of the Materials of Engineering, and the Standardization of Specifications and the Methods of Testing.

3. The business of the said corporation is to be transacted in Philadelphia.

4. The said corporation is to exist perpetually.

5. The names and residences of the incorporators are as follows:

HENRY M. HOWE, 27 West Seventy-third Street, New York.
CHARLES B. DUDLEY, Altoona, Pa.
EDGAR MARBURG, 517 South Forty-first Street, Philadelphia.
ROBERT W. LESLEY, 22 South Fifteenth Street, Philadelphia.
MANSFIELD MERRIMAN, South Bethlehem, Pa.
ALBERT LADD COLBY, South Bethlehem, Pa.
WILLIAM R. WEBSTER, "The Bartram," Thirty-third and Chestnut Streets, Philadelphia.

6. The management of the said corporation shall be vested in an Executive Committee, consisting of six (6) members, viz.: the Chairman, the Vice-Chairman, the Secretary, the Treasurer and two other members of the corporation, and such other officers as the corporation may from time to time appoint.

7. The corporation has no capital stock, and the members thereof shall be composed of the subscribers and their associates and of such persons as may from time to time be admitted by vote in such manner and upon such requirements as may be prescribed by the By-Laws. The corporation shall nevertheless have power to exclude, expel or suspend members for just or legal cause, and in such legal manner as may be ordained and directed by the By-Laws.

8. The By-Laws of this corporation shall be admitted and taken to be its laws subordinate to the statute aforesaid; this Charter; Constitution and Laws of the Commonwealth of Pennsylvania, and the Constitution of the United States; they shall be altered and amended as provided for by the By-Laws themselves; and shall prescribe the powers and functions of the Executive Committee herein mentioned and those to be hereafter elected, the times and places of meetings of the Committee and this corporation; the number of members who shall constitute a quorum at the meetings of the corporation, and of the Committee; the qualifications and manner of electing members; the manner of electing officers; and the powers and duties of such officers; and all other concerns and internal arrangements of the said corporation.

Witness our hands and seals this twenty-first day of March, A.D. 1902.

(Signed)
EDGAR MARBURG,
R. W. LESLEY,
WM. R. WEBSTER,
MANSFIELD MERRIMAN,
ALBERT LADD COLBY.

BY–LAWS.

ARTICLE I.

MEMBERS.

SECTION 1. Any person, corporation or technical society can become a member of this Society upon being proposed by two members and being approved by the Executive Committee.

SEC. 2. Any member who subscribes annually the sum of fifty dollars ($50) towards the general funds of the Society shall be designated a contributing member, his rights and privileges as a member remaining unchanged. Contributing members shall be exempt from the regular membership dues.

SEC. 3. Applications for membership and resignation from membership must be transmitted in writing to the Secretary.

ARTICLE II.

OFFICERS AND THEIR ELECTION.

SECTION 1. The officers shall be a President, Vice-President, Secretary and Treasurer.

SEC. 2. The offices of Secretary and Treasurer shall be held by the same person.

SEC. 3. These officers shall be elected by letter-ballot, at the Annual Meeting, and shall hold office for two years.

SEC. 4. The Executive Committee shall consist of these officers and also the last past-President and three members, two being elected by letter-ballot at each Annual Meeting in the odd years and one at each Annual Meeting in the even years.

SEC. 5. The President shall be, *ex officio*, the nominee for American Member of the Council of the International Association.

SEC. 6. The Secretary shall receive a salary to be fixed by the Executive Committee.

SEC. 7. The officers and members of the Executive Committee of this Society to hold office until the next election under these By-Laws, shall be as follows: To hold office for two years—President, Charles B. Dudley; Vice-President, R. W. Lesley; Secretary-Treasurer, Edgar Marburg; members of the Executive Committee, Henry M. Howe and James Christie. To hold office for one year—members of the Executive Committee, Albert Ladd Colby and John McLeod.

Sec. 8. The above officers and members of the Executive Committee, as well as all succeeding officers and members of the Executive Committee elected under these By-Laws, shall serve for the respective terms to which they shall have been elected, or until their successors shall have been duly elected.

Sec. 9. The Executive Committee shall have the power to fill any vacancies occurring in their number by death, resignation or otherwise.

Sec. 10. The election of officers and members of the Executive Committee shall be by letter-ballot. The Executive Committee, before each Annual Meeting, shall appoint a Nominating Committee, whose duty it shall be to nominate a full list of officers. The list of nominations so made shall be submitted to the membership not more than eight (8) nor less than four (4) weeks before the coming Annual Meeting.

Further nominations, signed by at least ten (10) members, may be submitted to the Secretary in writing at least four (4) weeks before the Annual Meeting, and such nominations shall also be submitted to the membership on the official ballot.

Article III.

MEETINGS.

Section 1. The Society shall meet annually. The time and place of each meeting shall be fixed by the Executive Committee.

Sec. 2. Special meetings may be called whenever the Executive Committee shall deem it necessary, or upon the request in writing to the President of twenty-five (25) members.

Article IV.

DUES.

Section 1. The fiscal year shall commence on the first of January, and all dues shall be payable in advance.

Sec. 2. The annual dues of each member shall be $5.00. Members holding membership also in the International Association for Testing Materials shall pay annually the additional sum of $1.50, which shall be transmitted by the Secretary to the International Association.

Sec. 3. Any member of the Society whose dues shall remain unpaid for the period of one year shall forfeit the privileges of membership. If he neglects to pay his dues within thirty days thereafter, and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Committee.

Article V.

Amendments.

Section 1. Proposed amendments to these By-Laws, signed by at least three members, must be presented in writing to the Executive Committee at least four weeks before the next Annual Meeting. In the notices for this meeting the proposed amendments shall be printed. At the Annual Meeting the proposed amendment may be discussed and amended and may be passed to letter-ballot by a two-thirds vote of those present.

If two-thirds of the votes obtained by letter-ballot are in favor of the proposed amendment, it shall be adopted.

Sec. 2. The Executive Committee is authorized to number the Articles and Sections of the By-Laws to correspond with any changes that may be made.

RULES GOVERNING THE EXECUTIVE COMMITTEE.

1. Regular meetings shall be held on the first Saturday in January, April, July and October. Four members shall constitute a quorum.

At each meeting the Secretary shall report the names of all new members and of members who have resigned during the previous quarter, and shall present a financial statement.

At the January meeting the Secretary shall report the names of all members whose dues are unpaid.

The accounts of the Secretary shall be duly audited at the middle and close of each fiscal year, and the report of the auditors shall be presented in writing at the July and January meetings.

2. Special meetings may be held at any time at the call of the President, or upon the written request of four members of the Executive Committee. The notice for such meetings shall be mailed by the Secretary at least one week in advance of the meeting, and the business shall be stated in the notice.

3. The Secretary shall transmit to the International Association within five days after the first day of January, April, July and October $1.50 for each member whose dues were paid in the previous quarter together with the names of those members.

No other expenses shall be paid except on vouchers certified to be correct by the Chairman of the Committee on Finance, or a member thereof designated by the Chairman.

GENERAL INFORMATION.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Historical.—The International Association for Testing Materials had its origin in a conference of a small group of workers in experimental engineering held in Munich in 1882, at the instance chiefly of the late John Bauschinger. Meetings on a larger scale were subsequently held in Dresden (1884), Berlin (1886), Munich (1888), Vienna (1893), and Zurich (1895). At the Zurich Congress the International Association for Testing Materials was formally organized, the Second Congress was held at Stockholm in 1897, the Third Congress met at Buda-Pesth in 1901, the Fourth Congress met at Brussels in 1906, and the Fifth Congress will assemble at Copenhagen in 1909.

Membership.—According to the latest official report (January, 1906) the membership is distributed as follows:

Germany, 344; Russia, 362; United States, 253; Austria, 178; France, 165; Switzerland, 75; Hungary, 76; Belgium, 45; England, 47; Italy, 47; Sweden, 50; Denmark, 50; Holland, 39; Norway, 37; Roumania, 18; Spain, 13; Portugal, 11; Servia, 3; Australia, 4; Luxemburg, 4; Brazil, 2; Argentine Republic, 1; Chili, 1; Japan, 1. Total, 1,826, representing 24 countries.

Objects.—The objects of the Association, as set forth in its By-Laws,* are: "The development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for that purpose."

The important subject of specifications has, however, also been included within the scope of the Association's activity. Thus, International Committee No. 1 has been charged to report on the following problem: "On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds."

Again, in pursuance of American initiative at the Buda-Pesth Congress (1901), Committee No. 1 has been enlarged by the addition of three American members, with a view of reporting on

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* These By-Laws are given in full on pp. 713-715.

"Standard International Specifications for Cast Iron and Finished Castings," and Committee No. 22 has been instructed to report "On the Feasibility of the Establishment of Standard International Specifications for Cements."

Administration.—The affairs of the Association are administered by a Council, consisting of the President and one representative (member of Council) from each country having a membership of twenty (20) or more.

Methods.—The original plan was to conduct investigations almost exclusively through the agencies of international committees. These committees proved unwieldy, however, by reason of their large membership, with the added difficulties arising from geographical separation and differences of language. In pursuance of resolutions at the Buda-Pesth Congress (1901) the Council has discharged some of these committees, reassigning the problems in part to individual referees.* In the case of questions of direct international concern the original international committees are continued.

At the international congresses the reports of these committees as well as individual contributions by members are presented and discussed.†

Publications.—On May 5, 1896, the International Council effected an arrangement with the publishers of *Baumaterialenkunde*‡ (Materials of Construction) by which that journal became the official organ of the Association. Since July, 1896, this journal has published the Proceedings of Congresses and other official matter in German and French. The fact that the Association did not furnish printed Proceedings to members free of charge,

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* For complete list of problems, committees and referees, see pp. 716-722.

† The papers presented at the Brussels Congress, 1906, are on sale at the following prices:

Official Papers, per set	$1.50
Non-official Papers, per set	2.50

Separate copies of above papers, 10–20 cents.
Report of Proceedings at Congress, 40 cents.

A list of official and non-official papers may be had by addressing: Edgar Marburg, University of Pennsylvania, Philadelphia, Pa.

‡ *Baumaterialenkunde:* Published bi-weekly at Stuttgart, Germany, in German and French. Regular subscription price $3.50 per annum; special terms to members of the International Association for Testing Materials, $2.50 per annum. Address: Staehle & Friedel, No. 57 Tuebinger Street, Stuttgart, Germany.

and that no provision had been made for translation into English, gave rise to no little dissatisfaction. At the Buda-Pesth Congress (1901) the International Council was accordingly authorized to perfect a new arrangement by which all official matter is now published in three separate editions (German, English and French) and sent free of charge to every member of the Association in whatever language is preferred.

ORGANIZATION OF THE AMERICAN MEMBERS OF THE INTERNATIONAL ASSOCIATION.

Historical.—With a view of bringing the members of like nationality into closer relations among themselves, and in order to simplify the management and render the work of the International Association more effective, it was decided at the Stockholm Congress (1897) to encourage the consolidation of the membership in the various countries into separate national organizations. In pursuance of this action the American members met in Philadelphia on June 16, 1898, and organized under the name of the "American Section of the International Association for Testing Materials."

In March, 1902, the Executive Committee of the American Section applied for a Charter under the laws of the State of Pennsylvania for purposes of incorporation under the proposed new name of the "American Society for Testing Materials." This Charter was duly granted, and at the Fifth Annual Meeting, held at Atlantic City, N. J., it was unanimously adopted on June 12, 1902.

At the Eighth Annual Meeting (1905) the By-Laws were amended with a view of leaving membership in the International Association to the individual option of the members of the American Society. This amendment was adopted by letter-ballot of the Society.

Objects.—The objects of the Society are essentially identical with those of the International Association, with which it stands in direct organic relation, both through its membership in the same as a body, and through the individual membership on the part of many of its members.

As stated in the Charter: "The corporation is formed for the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing."

The standardization of specifications is considered one of the most important functions of the Society. The method of procedure is to submit proposed standard specifications prepared by the various committees for general discussion at the annual meetings of the Society. The specifications in their original or amended form are then referred, by majority vote, to letter-ballot of the Society for adoption as Standard Specifications. A list of the Standard Specifications thus far adopted by the Society is given on page 730.

Representation on the International Council.—The American members are entitled to one representative on the International Council. By the new Statutes of the Association (1901): "the members of Council shall be proposed by the members of each country; their final appointment being confirmed by the Congress." According to the By-Laws of the American Society the President becomes, "*ex officio*, the nominee for American Member of the Council of the International Association."

Meetings.—The Society meets annually at a time and place fixed by the Executive Committee. Special meetings may also be called in accordance with the provisions of the By-Laws.

Annual meetings have been held in past years as follows:

First Annual Meeting, Philadelphia, Pa., House of Engineers' Club of Philadelphia, August 27, 1898.

Second Annual Meeting, Pittsburg, Pa., Rooms of Engineers' Society of Western Pennsylvania, August 15, 16, 1899.

Third Annual Meeting, New York, N. Y., House of American Society of Mechanical Engineers, October 25, 26, 27, 1900.

Fourth Annual Meeting, Niagara Falls, N. Y., International Hotel, June 29, 1901.

Fifth Annual Meeting, Atlantic City, N. J., Hotel Traymore, June 12, 13, 14, 1902.

Sixth Annual Meeting, Delaware Water Gap, Pa., Hotel Kittatinny, July 1, 2, 3, 1903.

Seventh Annual Meeting, Atlantic City, N. J., Hotel Traymore, June 16, 17, 18, 1904.

Eighth Annual Meeting, Atlantic City, N. J., Hotel Chalfonte, June 29–July 1, 1905.

Ninth Annual Meeting, Atlantic City, N. J., Hotel Chalfonte, June 21, 22, 23, 1906.

Tenth Annual Meeting, Atlantic City, N. J., Hotel Chalfonte, June 20, 21, 22, 1907.

Membership.—The number of American members at the time of the organization meeting in 1898 was 70. The membership reported at the successive annual meetings was as follows: (1899) 128, (1900) 160, (1901) 168, (1902) 175, (1903) 349, (1904) 485, (1905) 677, (1906) 835, (1907) 925, and it is now (October, 1907) 970.

Methods.—The operations of the Society are conducted in part under the auspices of the International Association and in part independently.

The number of American representatives on international committees is fixed by the International Council. These American sub-committees are authorized, however, to increase their number at pleasure, subject always to the approval of the Executive Committee of the American Society. The sense of these enlarged sub-committees on all questions is determined by majority vote; but on the international committees the representation and the number of votes allowed remain as originally fixed by the International Council.

The American Society appoints other committees at its discretion entirely independently of the International Association. On committees concerned with subjects involving commercial interests, the policy is to accord equal numerical representation to engineers or scientists, and to manufacturers.

The Committees of the American Society are now as follows:

A. On Standard Specifications for Iron and Steel.
B. On Standard Specifications for Cast Iron and Finished Castings.
C. On Standard Specifications for Cement.
D. On Standard Specifications for Paving and Building Brick.
E. On Preservative Coatings for Iron and Steel.
F. On Heat Treatment of Iron and Steel.
G. On The Magnetic Properties of Iron and Steel.
H. On Standard Tests for Road Materials.
I. On Reinforced Concrete.
J. On Standard Specifications for Coke.
K. On Standard Methods of Testing.
L. On Standard Specifications and Tests for Clay and Cement Sewer Pipes.
M. On Standard Specifications for Staybolt Iron.
N. On Standard Tests for Lubricants.
O. On Uniform Speed in Commercial Testing.
P. On Fireproofing Materials.
Q. On Standard Specifications for the Grading of Structural Timber.

R. On Uniform Specifications for Boilers.
S. On Waterproofing Materials.
T. On the Tempering and Testing of Steel Springs and Standard Specifications for Spring Steel.
U. On the Corrosion of Iron and Steel.

Publications.—The publications of the Society appeared originally at irregular intervals in the form of bulletins. Twenty-eight (28) bulletins, containing a total of 266 pages, were thus issued. In 1902 it was decided to publish the Proceedings thereafter in the form of annual volumes. In passing to this new plan of publication the twenty-eight bulletins previously issued were counted collectively as Volume I. The first of the annual volumes, designated Volume II and issued in 1902, contains 388 pages; Volume III, issued in 1903, contains 490 pages; Volume IV, issued in 1904, contains 655 pages; Volume V, issued in 1905, contains 565 pages; Volume VI, issued in 1906, contains 712 pages; Volume VII contains 759 pages.*

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* For Table of Contents of Previous Publications, see pp. 720–729.

OFFICERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

PRESIDENT,
CHARLES B. DUDLEY.

VICE-PRESIDENT,
R. W. LESLEY.

SECRETARY-TREASURER,
EDGAR MARBURG.
Office: University of Pennsylvania, Philadelphia, Pa.

MEMBERS OF THE EXECUTIVE COMMITTEE:

Term Expiring in 1908.

JAMES CHRISTIE, HENRY M. HOWE.

Term Expiring in 1909.

W. A. BOSTWICK, WM. R. WEBSTER.

STANDING COMMITTEES.

COMMITTEE ON FINANCE.

WM. R. WEBSTER, *Chairman*, W. A. BOSTWICK.
R. W. LESLEY.

COMMITTEE ON MEMBERSHIP.

JAMES CHRISTIE, *Chairman*, R. W. LESLEY,
EDGAR MARBURG.

COMMITTEE ON PUBLICATIONS.

HENRY M. HOWE, *Chairman*, W. A. BOSTWICK.
EDGAR MARBURG.

LIST OF MEMBERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

Affiliated with the International Association for Testing Materials

Members holding membership also in the International Association are distinguished thus (*).

Contributing members are distinguished thus (†)

ELECTED.

1906. Abrams, D. A. Assistant, Laboratory of Applied Mechanics, University of Illinois, Urbana, Ill.

1906. Ackenheil, J. D. Salesman, The Patterson, Sargent Company, 42 Hudson Street, New York, N. Y.

1905. Adair, Arthur P. Civil Engineer, Room 327, Sonna Block, Boise, Idaho.

1904. Adams, Hugh W. Eastern Agent, Sloss-Sheffield Steel and Iron Company, 15 Beekman Street, New York, N. Y.

1904. Aiken, Charles W. Consulting Engineer, 101 Castleton Avenue, West New Brighton, Staten Island, N. Y.

1902. Aiken, W. A. General Inspector of Material, Rapid Transit Railroad Commission of New York, 613 Empire Building, Pittsburg, Pa.

1902. *†Ajax Metal Company. G. H. Clamer, Second Vice-President and Secretary, 46 Richmond Street, Philadelphia, Pa.

1904. Allcott, F. L. Engineer of Tests, Chicago, Milwaukee and St. Paul Railway, Milwaukee, Wis.

1903. Allen, A. W. Superintendent, Steel Department, Pencoyd Iron Works, 267 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

1905. Allen, Henry C. Special Deputy State Engineer, DeGraaf Building, Albany, N. Y.

1904. Allen, Walter H. Civil Engineer, United States Navy, Navy Yard, Charleston, S. C.

1906. Allien, Victor S. Protective Coatings, 39 East Forty-second Street, New York, N. Y.

1905. American Asphaltum and Rubber Company. T. J. Hill, President, 721 Woman's Temple, Chicago, Ill.

ELECTED.

1902. AMERICAN BRIDGE COMPANY. C. C. Schneider, Consulting Engineer, Fifteenth and Chestnut Streets, Philadelphia, Pa.

1904. *AMERICAN BUREAU OF INSPECTION AND TESTS. E. B. Wilson, Secretary and Treasurer, 930 Monadnock Block, Chicago, Ill.

1906. AMERICAN BUREAU OF SHIPPING. Joseph E. Borden, Chief Engineer, 66 Beaver Street, New York, N. Y.

1898. *AMERICAN FOUNDRYMEN'S ASSOCIATION. Richard Moldenke, Secretary, Watchung, N. J.

1905. AMERICAN IRON AND STEEL MANUFACTURING COMPANY. H. M. Sternbergh, Vice-President and General Manager, Reading, Pa.

1904. *AMERICAN MACHINIST. Fred. J. Miller, Editor, 505 Pearl Street, New York, N. Y.

1897. AMERICAN SOCIETY OF MECHANICAL ENGINEERS. F. R. Hutton, Secretary, 12 West Thirty-first Street, New York, N. Y.

1900. AMERICAN STEEL AND WIRE COMPANY. F. H. Daniels, Chief Engineer, Worcester, Mass.

1906. *ANACONDA COPPER MINING COMPANY. E. P. Mathewson, Manager, Reduction Works, Anaconda, Mont.

1905. *ANDERSON, HAROLD BENTLEY. Mechanical Engineer, The Winton Motor Carriage Company, Cleveland, O.

1906. ANDREWS, W. H. Manager, Pratt and Lambert, 79 Tonawanda Street, Buffalo, N. Y.

1904. ANGUS, W. F. Engineer, Montreal Steel Works, Limited, Montreal, Canada.

1906. ANTISELL, FRANK L. Constructing Engineer, Raritan Copper Works, Perth Amboy, N. J.

1902. ARNOLD, CHARLES E. Chemist, Experimental Department, duPont Company. *For Mail*, 1516 Van Buren Street, Wilmington, Del.

1906. ARNOLD, C. M. Cement Inspector, Baltimore and Ohio Railroad Company, Sixteenth and Main Streets, Wheeling, W. Va.

1906. ASHBRIDGE, RICHARD I. D. Chief Engineer, New Jersey Short Line Railroad, 605 Land Title Building, Philadelphia, Pa.

1907. ASSOCIATION OF LICENSED AUTOMOBILE MANUFACTURERS. Coker F. Clarkson, Secretary, 7 East Forty-second Street, New York, N. Y.

ELECTED.

1906. AUSTEN, PETER T. Consulting Chemist, 89 Pine Street, New York, N. Y.

1904. AVERILL, F. L. Civil Engineer, Washington Representative of Robert W. Hunt and Company, Room 414, Colorado Building, Washington, D. C.

1905. AVIS, JAMES L., JR. Mechanical Engineer, Robert W. Hunt and Company, 1121 The Rookery, Chicago, Ill.

1902. *BAILEY, J. B. Treasurer and General Manager, Central Iron and Steel Company, Harrisburg, Pa.

1906. BAILEY, RALPH W. Chemist, 65 Columbia Heights, Brooklyn, N. Y.

1903. BAKENHUS, R. E. Civil Engineer, United States Navy. In charge of Engineering Work, Naval Training Station, Newport, R. I.

1903. BAKER, IRA O. Professor of Civil Engineering, University of Illinois, Champaign, Ill.

1904. BAKER AND CO., W. E. Engineers, 27 William Street, New York, N. Y.

1904. BALDWIN, STEPHEN W. A. L. Endicott, Hyslop Road, Fisher Hill, Brookline, Mass.

1907. BALLENTINE, WILLIAM H. Engineer of Works, Link-Belt Company, Chicago, Ill.

1907. BANGS, C. R. Special Agent, American Telephone and Telegraph Company, 15 Dey Street, New York, N. Y.

1904. *BARBER ASPHALT PAVING COMPANY. J. L. Rake, General Agent, Land Title Building, Philadelphia, Pa.

1898. BARBOUR, FRANK A. Civil Engineer, Snow and Barbour, 1121 Tremont Building, Boston, Mass.

1904. BARNES, CHARLES B. 360 East Sixty-second Street, Chicago, Ill.

1904. *BARNSLEY, GEORGE T. Chief Road Engineer, County of Allegheny, Pittsburg, Pa.

1905. BARRETT MANUFACTURING COMPANY. W. S. Babcock, 17 Battery Place, New York, N. Y.

1904. *BASQUIN, OLIN H. Associate Professor of Physics, Northwestern University, Evanston, Ill.

1903. *BASSETT, WILLIAM H. Chemist in charge of Laboratories, Coe Brass Manufacturing Company, Torrington, Conn.

1903. BATEMAN, F. W. Civil Engineer, Clinton, Mass.

1907. BAXTER, FLORUS R. Chief of Testing Laboratory, Vacuum Oil Company, 926 Exchange Street, Rochester, N. Y.

ELECTED.

1906. Beale, A. H. Manager, The Eastern Steel Company, Pottsville, Pa.

1904. Beck, Wesley J. Superintendent, Electrical Department, American Rolling Mill Company, Middletown, Ohio.

1903. Beckett, James A. General Superintendent, Walter A. Wood Mower and Reaper Company, Hoosick Falls, N. Y.

1907. Beckstrand, E. H. Professor of Mechanical Engineering, University of Utah, Salt Lake City, Utah.

1904. Beebe, T. E. Superintendent, International Cement Company, Elizabeth, Pa.

1906. Belden, A. W. Coke Expert, United States Geological Survey, Fuel Testing Plant, West Cedar, D. & R. G. Tracks, Denver, Col.

1907. Belfour, Percy F. Chemist, Marlbank, Ontario, Can.

1907. *Bement, A. Consulting Engineer, American Trust Building, Chicago, Ill.

1907. Bent, H. B. Engineer of Tests, Pennsylvania Steel Company, Steelton, Pa.

1902. *Berger, Bernt. Civil Engineer, Assistant Engineer to Theodore Cooper, 45 Broadway, New York, N. Y.

1904. *Bergquist, J. G. Superintendent, Cement Plant, Illinois Steel Company, Chicago, Ill.

1904. *Berle, Kort. Chief Structural Engineer, Supervising Architect's Office, Washington, D. C.

1903. Berrall, James. Civil Engineer, Bond Building, Washington, D. C.

1905. Berry, H. C. Instructor in Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

1898. Bethlehem Steel Company. E. O'C. Acker, South Bethlehem, Pa.

1904. Betts, H. S. Testing Engineer, Bureau of Forestry, Washington, D. C.

1904. Bird, Robert M. Superintendent, Treatment Department, Bethlehem Steel Company, 433 Brodhead Avenue, South Bethlehem, Pa.

1905. Birkinbine, John. Consulting Engineer, Odd Fellows' Temple, Philadelphia, Pa.

1906. Bishop Company, J. W. 109 Foster Street, Worcester, Mass.

1896. Bissell, George W. Professor of Mechanical Engineering, Iowa State College, Ames, Iowa.

1903. *Bixby, W. H. Colonel, Corps of Engineers, United States Army, Room 504, Federal Building, Chicago, Ill.

ELECTED.

1904. Black, Adolph. Instructor in Civil Engineering, Columbia University, New York, N. Y.

1904. Blanch, Joseph C. Superintendent, Blanchite Process Paint Company, 139 Charles Street, New York, N. Y.

1905. Blauvelt, W. H. Managing Engineer, Semet Solvay Company, Syracuse, N. Y.

1905. Blauvelt, Warren S. Superintendent, Coke Oven Department, The Solvay Process Company, Detroit, Mich.

1902. Bliss, Collins P. Professor of Mechanical Engineering and Director of Testing Laboratory, New York University, University Heights, New York, N. Y.

1906. Blough, Earl. Chief Chemist, Pittsburg Reduction Company, Pittsburg, Pa.

1906. Böcking, Ferdinand. Foundryman, Halbergerhütte, Brebach a. Saar, Germany

1903. Böcking, Rudolph. Halbergerhutte, Post Brebach, Germany.

1905. Bole, Wm. A. Manager of Works, Westinghouse Machine Company, East Pittsburg, Pa.

1903. *Boller and Hodge. Consulting Engineers, 1 Nassau Street, New York, N. Y.

1902. Bonzano, A. President, Bonzano Rail-Joint Company, 331 South Eighteenth Street, Philadelphia, Pa.

1896. Booth, Garrett and Blair. Engineers and Chemists, 406 Locust Street, Philadelphia, Pa.

1905. *Borgner, Cyrus. Fire Brick and Cement Manufacturer, Twenty-third Street above Race Street, Philadelphia, Pa.

1904. *Bostwick, W. A. (*Member of Executive Committee*) Metallurgical Engineer, Carnegie Steel Company, Pittsburg, Pa.

1905. Boughton, W. H. Professor of Civil Engineering, West Virginia University, Morgantown, W. Va.

1904. *Bowman, Austin Lord. Consulting Engineer; Bridge Engineer, Central Railroad Company of New Jersey, 29 Broadway, New York, N. Y.

1907. Boylston, H. M. Assistant in Metallurgy and Metallography, Harvard University, Rotch Building, Cambridge, Mass.

1902. Boynton, C. W. Chief Inspector, Cement Department, Illinois Steel Company, 1063 The Rookery, Chicago, Ill.

1907. Boynton, Henry C. Metallurgist, John A. Roebling's Sons Company, Trenton, N. J.

ELECTED.

1900. BRAINE, L. F. Vice President, The Rail-Joint Company, Newark, N. J.

1898. BRAMWELL, JOSEPH W. 4931 Rubicam Avenue, Germantown, Philadelphia, Pa.

1906. BRAZER, G. HERBERT. Civil Engineer, J. R. Worcester and Company, 79 Milk Street, Boston, Mass.

1904. BREGOWSKY, IVAN M. Metallurgist, Crane Company, 51 Judd Street, Chicago, Ill.

1906. *BRIGHT, H. DE H. Manager, Spring Department, Standard Steel Works, 811 Harrison Building, Philadelphia, Pa.

1907. BROOM, WILLIAM. President, The Arlington Manufacturing Company, Canton, O.

1899. BROADHURST, W. H. Chemist, Department of Public Works, Municipal Building, Brooklyn, N. Y.

1905. BROWN AND COMPANY, INCORPORATED, Wayne Iron and Steel Works. James Neale, Secretary, Pittsburg, Pa.

1907. BROWN, CHARLES S. Professor of Mechanical Engineering, Vanderbilt University, Nashville, Tenn.

1906. BROWN HOISTING MACHINERY COMPANY, THE. Cleveland, Ohio.

1904. *BROWN, JOHN G. 809 North Forty-first Street, Philadelphia, Pa.

1906. BROWN, RICHARD P. 311 Walnut Street, Philadelphia, Pa.

1904. BROWN, SAMUEL A. Inspector of Cement, Philadelphia Rapid Transit Company, 812 Sansom Street, Philadelphia, Pa.

1905. BROWN, WM. L. Test Department, Pennsylvania Railroad, Altoona, Pa.

1906. BROWNE, ARTHUR L. Consulting Chemist, 213 Courtland Street, Baltimore, Md.

1903. *BRUNNER, JOHN. Assistant General Superintendent, Illinois Steel Company, 1732 Chicago Avenue, Evanston, Ill.

1905. BUCK, R. S. Consulting Engineer, Department of Bridges, New York, Park Row Building, New York, N. Y.

1903. BUCKLEY, E. R. Director, Missouri Bureau of Geology and Mines, State Geologist, Rolla, Mo.

1905. BUEL, HAMBDEN. V. C. Bogue, 15 William Street, New York, N. Y.

1906. BUFFALO TESTING LABORATORY, George A. Ricker, President, 702 Elliott Square, Buffalo, N. Y.

1904. *BUNNELL, F. O. Engineer of Tests, Chicago, Rock Island and Pacific Railway, Chicago, Ill.

ELECTED.

1902. **Burdett, F. A.** Consulting Engineer, 29 West Thirty-fourth Street, New York, N. Y.

1907. **Burn, John H.** Inspector, Rail Joint Company, 519 West Seventh Street, Chester, Pa.

1906. **Burnap, Arthur M.** Inspecting and Testing Engineer, 437 Drexel Building, Philadelphia, Pa.

1903. **Burnham, Raymond.** Associate Professor of Experimental Engineering, Armour Institute of Technology, Chicago, Ill.

1899. ***Burr, William H.** Professor of Civil Engineering, Columbia University, New York, N. Y.

1906. ***Bush, Harold M.** Mechanical Engineer, 215 New Hayden Building, Columbus, Ohio.

1905. **Buss, Edward A.** Consulting Engineer, 85 Water Street, Boston, Mass.

1903. ***Buzzi, P. D.** Jefe del Laboratorio de Obras Publicas, Arsenal, Havana, Cuba.

1906. **Calman and Company, Emil.** Varnish Manufacturers, 299 Pearl Street, New York, N. Y.

1904. **Cairns, Edward T.** General Agent, The North British and Mercantile Insurance Company, 76 William Street, New York, N. Y.

1902. **Cambier, Jacob.** Chemist, Colorado Fuel and Iron Company, 910 Spruce Street, Pueblo, Colo.

1899. ***†Cambria Steel Company.** George E. Thackray, Structural Engineer, Johnstown, Pa.

1907. **Campbell, Charles M.** 128 Garvine Avenue, Elyria, O.

1903. ***Campbell, William.** Adjunct Professor of Metallography, School of Mines, Columbia University, New York, N. Y.

1906. **Canals, I. A.** Civil Engineer, Post Office Box 436, San Juan, P. R.

1898. **Capp, John A.** Engineer, Testing Laboratory, General Electric Company, Schenectady, N. Y.

1906. ***Carbon Steel Company.** James Johnson, General Superintendent, Thirty-second and Smallman Streets, Pittsburg, Pa.

1906. **Carmody, John M.** Inspector, Ambridge, Pa.

1898. **†Carnegie Steel Company.** W. A. Bostwick, Metallurgical Engineer, Pittsburg, Pa.

1903. ***Carney, F. D.** Assistant Superintendent, The Pennsylvania Steel Company, Steelton, Pa.

ELECTED.

1902. CARPENTER, LOUIS G. Professor of Civil and Irrigation Engineering, and Director of Experiment Station, Fort Collins, Colo.

1895. CARPENTER, ROLLA C. Professor of Experimental Engineering, Cornell University, 31 Eddy Street, Ithaca, N. Y.

1903. *CARPENTER STEEL COMPANY, THE. George W. Sargent, Metallurgist, Reading, Pa.

1907. CARPENTER, WILLIAM M. Vice-President, Walworth and Neville Manufacturing Company, 1505 Heyworth Building, Chicago, Ill.

1906. CARR, WM. M. Carr and Speer, 120 Liberty Street, New York, N. Y.

1904. CARTER, J. G. U. S. Inspector, Lock No. 6, Trinity River, Bristol, Texas.

1899. CARTER, ROBERT A. President, Monongahela Iron and Steel Company, Box 215, Pittsburg, Pa.

1903. CARTLIDGE, C. H. Bridge Engineer, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1905. CENTRAL IRON AND COAL COMPANY. J. Lodge, President, Tuscaloosa, Ala.

1902. *†CENTRAL IRON AND STEEL COMPANY. James B. Bailey, Treasurer and General Manager, Harrisburg, Pa.

1906. CHADSEY, STANLEY B. Chemist, International Harvester Company of Canada, Ltd., Hamilton, Ontario, Canada.

1905. CHAMBERLAIN, PAUL R. 5906 White Avenue, N. E., Cleveland, O.

1905. CHAMPION, E. C. Superintendent, Kansas Portland Cement Company, Iola, Kans.

1907. CHANDLER, B. L. Treasurer, Beckwith-Chandler Company, 201 Emmett Street, Newark, N. J.

1907. CHARLS, G. H. Assistant Secretary, The American Rolling Mill Company, Middletown, O.

1904. CHEESMAN, FRANK P. National Paint Works, Elliot and Cheesman, 100 William Street, New York, N. Y.

1905. CHRISTIAN, EDMUND. Manager, Norfolk Creosoting Company, Buell, Va.

1907. CHRISTIE, ALEXANDER J. Engineer of Tests, American Bridge Company, Ambridge, Pa.

1898. CHRISTIE, JAMES (*Member of Executive Committee*). Mechanical Engineer, 100 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

ELECTED.

1907. CHURCH, SUMNER R. American Coal Products Company, 17 Battery Place, New York, N. Y.

1900. *CHURCHILL, CHARLES S. Chief Engineer, Norfolk and Western Railway, Roanoke, Va.

1906. CINCINNATI CHAPTER, AMERICAN INSTITUTE OF ARCHITECTS. A. O. Elzner, Secretary, 136 Ingalls Building, Cincinnati, Ohio.

1905. *CIVIL ENGINEERS' CLUB OF CLEVELAND, THE. Jos. C. Beardsley, Secretary, 718 Caxton Building, Cleveland, O.

1905. CLAPP, WILFRED A. Civil Engineer, United States Quartermaster's Department, 103 Sherman Street, Portland, Me.

1907. CLARK, EDWIN. Chief of Bureau of Building Inspection, 317 City Hall, Philadelphia, Pa.

1900. *CLARK, F. H. General Superintendent of Motive Power, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1905. CLARKE, D. D. Civil Engineer, Water Board, City Hall, Portland, Ore.

1905. CLARKE, ST. JOHN. Chief Engineer, New York and Long Island Railroad, 16 East Forty-second Street, New York, N. Y.

1904. CLARKSON MEMORIAL SCHOOL OF TECHNOLOGY, THOMAS S. William S. Aldrich, Director, Potsdam, N. Y.

1905. CLEMENTS, FRANK O. Chemist, National Cash Register Company, Dayton, Ohio.

1904. CLIFTON, CHARLES H. First Assistant, Philadelphia Municipal Testing Laboratory, 318 City Hall, Philadelphia, Pa.

1907. CLINE, MCGARVEY. Engineer in Timber Tests, Forest Service, Washington, D. C.

1907. COBB, EDWARD S. Engineer, 696 Pacific Electric Building, Los Angeles, Cal.

1905. COE, EDWARD K. U. S. Junior Engineer, 1411 East Third Street, Duluth, Minn.

1899. COLBY, ALBERT LADD. 217 West One Hundred and Tenth Street, New York, N. Y.

1899. COLBY, J. ALLEN. Inspecting Engineer, Witherspoon Building, Philadelphia, Pa.

1904. COLLES, GEORGE W. Consulting Mechanical and Electrical Engineer, 408 Alhambra Building, Milwaukee, Wis.

1900. *COLORADO FUEL AND IRON COMPANY. J. B. McKennan, Manager, Minnequa Plant, Pueblo Colo.

ELECTED.

1905. CONDIT, E. A., JR. Inspector, Continuous Rail Joint Company, 520 Summer Avenue, Newark, N. J.

1905. CONDIT, FILLMORE. Manager, California Asphaltum Sales Agency, 11 Broadway, New York, N. Y.

1900. CONDRON, T. L. Consulting Engineer, 1442 Monadnock Building, Chicago, Ill.

1904. CONLIN, FREDERICK. General Manager, Bethlehem Foundry and Machine Company, Lehigh Foundry Company, 355 Market Street, Bethlehem, Pa.

1906. CONOVER, H. SPENCER. Cement Inspector, Cementon, Pa.

1904. CONRADSON, P. H. Chief Chemist, Galena Signal Oil Company, Franklin, Pa.

1905. CONVERSE, W. A. Directing Chemist, Dearborn Drug and Chemical Works, 227–234 Rialto Building, Chicago, Ill.

1906. COOK, D. S. Superintendent, Speed Mills, Louisville Cement Company, Sellersburg, Ind.

1903. COOK, EDGAR S. President, Warwick Iron and Steel Company, Pottstown, Pa.

1907. COOPER, WILLIAM A. Superintendent, Schuylkill Iron Works, Alan Wood Iron and Steel Company, Conshohocken, Pa.

1906. *CORNELL UNIVERSITY LIBRARY. George W. Harris, Librarian, Ithaca, N. Y.

1899. *CORTHELL, E. L. Civil Engineer, 1 Nassau Street, New York, N. Y.

1902. COSBY, SPENCER. Captain, Corps of Engineers, United States Army, care of War Department, Washington, D. C.

1906. *COWAN, GEORGE P. Assistant Engineer, Department of Engineering and Public Works, Manila, P. I.

1903. COWEN, HERMAN C. Superintendent, Catskill Cement Company, Smith Landing, Greene County, N. Y.

1906. CRAWFORD, D. F. General Superintendent, Motive Power, Pennsylvania Railroad Lines West, Room 1106, Union Station, Pittsburg, Pa.

1905. CRAWFORD, HARRY C. Inspector, Railway Equipments, Fox Chase, Philadelphia, Pa.

1907. CROCKARD, FRANK H. Vice-President and General Manager, Tennessee Coal, Iron and Railroad Company, Woodward Building, Birmingham, Ala.

1906. CROMWELL, O. C. Mechanical Engineer, Baltimore and Ohio Railroad Company, Mount Clare, Baltimore, Md.

ELECTED.

1907. CROSS, WALTER M. City Chemist, City Hall, Kansas City, Mo.

1904. *CROWELL, BENEDICT. Mining Engineer, 731 Williamson Building, Cleveland, O.

1903. CROXTON, H. A. President, Massillon Iron and Steel Company, Massillon, O.

1899. *CRUIKSHANK, BARTON. The Solway Process Company, Syracuse, N. Y.

1904. CUMMINGS, ROBERT A. Consulting and Contracting Engineer, 4 Smithfield Street, Pittsburg, Pa.

1906. CUSHING, W. C. Chief Engineer, Maintenance of Way, Pennsylvania Lines, South West System, Union Station, Pittsburg, Pa.

1904. CUSHMAN, ALLERTON S. Chemist, Road Material Laboratory, United States Department of Agriculture, Washington, D. C.

1906. DAMON, GEORGE A. Managing Engineer, The Arnold Company, Borland Building, Chicago, Ill.

1900. *DAVIDSON, GEORGE M. Engineer of Tests, Chicago and Northwestern Railroad, Chicago, Ill.

1907. DAVIES, GEORGE C. Pilling and Crane, 600 Girard Trust Building, Philadelphia, Pa.

1907. DAVIS AND COMPANY, JAMES H. Portland Cement, 92 State Street, Boston, Mass.

1904. *DAVIS, CHANDLER. Department of Docks and Ferries, Pier "A," North River, New York, N. Y.

1905. DAVIS, CHARLES HENRY. South Yarmouth, Mass.

1906. DAVIS, J. C. Assistant First Vice-President, American Steel Foundries, Chicago, Ill.

1904. DAVIS, NATHAN H. President, Davis Solid Truss Brake Beam Company, Wilmington, Del.

1903. *DAVIS, WILLIAM R. Chief Bridge Designer, State Engineer's Office, Albany, N. Y.

1904. DAVIS, WILLIAM M. Oil Inspector, in Charge of Lubrication, American Sheet and Tin Plate Company, Sheridanville, Allegheny County, Pa.

1902. *DE ARMOND, W. C. President, Protectus Company, 1103 North American Building, Philadelphia, Pa.

1906. *DECEW, J. A. Consulting Chemical Engineer, Sun Life Building, Montreal, Canada.

ELECTED.

1905. *DEKNIGHT, EDWARD W. President and Manager, Hydrex Felt and Engineering Company, 120 Liberty Street, New York, N. Y.

1906. *DEROODE, RUDOLF. Superintendent, Bureau of Tests, International Paper Company, Glens Falls, N. Y.

1905. DEWOLF, R. D. Electrical Engineer, Westinghouse Electric and Manufacturing Company, 508 Rebecca Street, Wilkinsburg, Pa.

1904. DE WYRALL, CYRIL. Chief Inspector, Interborough Rapid Transit Company, New York City. *For Mail*, Ridgefield Park, N. J.

1899. *DEANS, JOHN STERLING. Chief Engineer, Phœnix Bridge Company, Phœnixville, Pa.

1906. DENNIS, D. B. The Patterson, Sargent Company, 42 Hudson Street, New York, N. Y.

1906. DEPARTMENT OF CIVIL ENGINEERING, CASE SCHOOL OF APPLIED SCIENCE. F. H. Neff, Professor of Civil Engineering, Cleveland, Ohio.

1904. DEPARTMENT OF ENGINEERING, TUFTS COLLEGE. Gardner C. Anthony, Dean, Tufts College, Mass.

1902. DERLETH, CHARLES, JR. Professor of Structural Engineering, University of California, Berkeley, Cal.

1907. DES ANGES, HENRY L. Superintendent, Floating Equipment, Long Island Railroad Company, Long Island City, N. Y.

1904. DETROIT GRAPHITE MANUFACTURING COMPANY. F. W. Davis, Jr., Second Vice-President, 141 Broadway, New York, N. Y.

1903. DEVERELL, H. F. Secretary, Otis Steel Company, Cleveland, O.

1905. DICKERSON, W. H. Assistant Engineer of Tests, Union Pacific Railroad, 3708 North Twenty-first Street, Omaha, Neb.

1907. DILKS, L. C. Eastern Steel Company, 71 Broadway, New York, N. Y.

1903. DILLER, H. E. Chemist, Hawthorne Engineering Laboratories, Western Electric Company, Chicago, Ill.

1904. DINAN, EDWARD. Chemist, Edison Portland Cement Company, 230 East Third Street, South Bethlehem, Pa.

1902. DIXON CRUCIBLE COMPANY, JOSEPH. Malcolm McNaughton, Superintendent, Paint and Lubricating Department, Jersey City, N. J.

ELECTED.

1903. †DIXON, R. M. Vice-President, The Safety Car Heating and Lighting Company, 2 Rector Street, New York, N. Y.

1901. *DOBLE, WILLIAM A. President, Abner Doble Company, Seventh and South Streets, San Francisco, Cal.

1907. DOKE, G. E. Chief Inspector, Lake Shore and Michigan Southern Railway Company, Collinwood, O.

1904. DOMINION BRIDGE COMPANY. Phelps Johnson, Manager, Montreal, Canada.

1905. *DONOHOE, JOHN P. Vice-President and General Manager, Donohoe Coke Company, Greensburg, Pa.

1907. DOUGHERTY, J. W. General Superintendent, Pennsylvania Steel Company, Steelton, Pa.

1906. DOUTY, D. E. Assistant Physicist, Bureau of Standards, Washington, D. C.

1898. *DOW, ALLAN W. 120 East Twenty-third Street, New York N. Y.

1903. DRUMMOND, M. J. President, Glamorgan Pipe and Foundry Company, 192 Broadway, New York, N. Y.

1905. DUBBS, C. P. General Manager, Globe Asphalt Company, 310 Togo Building, Los Angeles, Cal.

1904. DUBBS, J. A. President, Globe Asphalt Company, 405 Bakewell Building, Pittsburg, Pa.

1902. DU COMB, W. C., JR. Engineer of Tests, Davis Solid Truss Brake Beam Company, Wilmington, Del.

1896. *†DUDLEY, CHARLES B. (*President*). Chemist, Pennsylvania Railroad, Altoona, Pa.

1902. DUDLEY, P. H. Consulting Engineer, 80 Pine Street, New York, N. Y.

1906. DUERR, H. O. General Manager, Diamond Stone Brick Company, Box 261, Wilmington, Del.

1901. DUFOUR, F. O. Assistant Professor of Structural Engineering, University of Illinois, Urbana, Ill.

1902. DUMARY, L. HENRY. President, The Helderberg Cement Company, 38 State Street, Albany, N. Y.

1902. DUNBAR, W. O. Assistant Engineer, Testing Department, Pennsylvania Railroad, Altoona, Pa.

1904. DUNN, W. R. Superintendent, Vulcanite Portland Cement Company, Phillipsburg, N. J.

1905. DUNNING, HUBERT. National Lead Company, 100 William Street, New York, N. Y.

ELECTED.

1904. DURYEE, E. Cement Expert, United States Reclamation Service, Roosevelt, Ariz.

1904. DWIGHT, THEODORE. Electrical Engineer, Post Office Box 223, New York, N. Y.

1907. DYER, E. H. Secretary and Treasurer, Mound City Paint and Color Company, St. Louis, Mo.

1905. EAGLE WHITE LEAD COMPANY. F. J. Baringer, Chemist, Cincinnati, O.

1902. EASBY, M. WARD. Consulting Engineer, 909 Crozer Building, Philadelphia, Pa.

1906. EASTERBROOKS, FRANK D. Chemical Engineer, Box 2139, Bridgeport, Conn.

1905. EATON, LEWIS G. Sandusky Portland Cement Company, Syracuse, Ind.

1902. EDWARDS, WARRICK R. Assistant Engineer, Baltimore and Ohio Railroad, Baltimore and Ohio Building, Baltimore, Md.

1905. *EHRENFELD, CHARLES H. Chemist, York Manufacturing Company, York, Pa.

1904. *EIDLITZ, OTTO M. Civil Engineer, 489 Fifth Avenue, New York, N. Y.

1905. ELLIS, THEODORE H. President, The Ellis Company, 641 Calvert Building, Baltimore, Md.

1907. ELY, EDWARD F. Architect, 32 Westminster Street, Providence, R. I.

1896. *ELY, THEODORE N. Chief of Motive Power, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1905. ELZNER, A. O. Architect, 136 Ingalls Building, Cincinnati, O.

1898. ENGINEERING RECORD. 239 West Thirty-ninth Street, New York, N. Y.

1905. ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. F. V. McMullin, Secretary, 803 Fulton Building, Pittsburg, Pa.

1905. ENGINEERS' CLUB OF CINCINNATI. E. A. Cast, Secretary-Treasurer, Post Office Box 333, Cincinnati, O.

1905. ENRIGHT, BERNARD. Chief Chemist, Virginia Portland Cement Company, Fordwick, Augusta County, Va.

1903. *ERLANDSEN, OSCAR. Chief Engineer, O'Rourke Engineering Construction Company, 1 West Thirty-fourth Street, New York, N. Y.

ELECTED.

1903. ESTERLINE, J. WALTER. Assistant Professor of Electrical Engineering, Purdue University, Lafayette, Ind.

1905. *ESTILL, HOWARD S. President Big Sandy Fuel Company, Paintville, Ky.

1905. EVANS, D. T. General Manager, The Mount Carbon Company, Limited, Powellton, W. Va.

1906. EVANS, R. W. Treasurer, Picher Lead Company, 511 Tacoma Building, Chicago, Ill.

1904. EVANS, S. M. Manager New York Office, Picher Lead Company, 100 William Street, New York, N. Y.

1904. EWEN, JOHN M. Vice-President, Thompson-Starrett Company, 1402 Railway Exchange, Chicago, Ill.

1905. EWING, W. W. Engineer, Westinghouse, Church, Kerr and Company, 10 Bridge Street, New York, N. Y.

1904. *FACKENTHAL, JR., B. F. President, Thomas Iron Company, Easton, Pa.

1903. FACULTY APPLIED SCIENCE, MCGILL UNIVERSITY. Henry T. Bovey, Dean, Montreal, Can.

1905. FALK, MYRON S. Consulting Engineer, 60 Wall Street, New York, N. Y.

1902. FALKENAU, A. 919 Witherspoon Building, Philadelphia Pa.

1902. FARREL FOUNDRY AND MACHINE COMPANY. Walter Perry, Manager, Foundry Department, Ansonia, Conn.

1902. FAY, HENRY. Professor of Analytical Chemistry, Massachusetts Institute of Technology, Boston, Mass.

1903. FENNER, L. M. Chemical Engineer, H. H. Franklin Manufacturing Company, 342½ Delaware Street, Syracuse, N. Y.

1907. FERGUSON, F. W. Architect, 15 Beacon Street, Boston, Mass.

1905. FERNOW, B. E. Consulting Forest Engineer, 42 Broadway, New York, N. Y.

1906. FINDLEY, A. I. Editor, *The Iron Age*, 14 Park Place, New York, N. Y.

1905. *FINN, GEORGE H. General Manager, The New England Gas and Coke Company, Old South Building, Boston, Mass.

1903. FITZ GERALD, FRANCIS A. J. Chemical Engineer, Fitz Gerald and Bennie Laboratories, Niagara Falls, N. Y.

1907. FITZGERALD, J. A. Engineer of Tests, Otis Steel Company, Limited, Cleveland, O.

ELECTED.

1899. FLAGG, STANLEY G., JR. Stanley G. Flagg and Company, Nineteenth Street and Pennsylvania Avenue, Philadelphia, Pa.

1904. *FLEMING, HENRY S. Consulting Engineer, 1 Broadway, New York, N. Y.

1906. FOLLER, CHARLES S. Mechanical Engineer, Union Spring Manufacturing Company, Farmers Bank Building, Pittsburg, Pa.

1907. *FORCE, H. J. Chemist and Engineer of Tests, Delaware, Lackawanna and Western Railroad Company, Scranton, Pa.

1904. FORD, ALLEN P. Metallurgist, Eaton, Cole and Burnham Company, Bridgeport, Conn.

1901. FORREST, C. N. Chief Chemist, New York Testing Laboratory, Maurer, N. J.

1903. FORSYTH, WILLIAM. Mechanical Engineer, *Railway Age*, Chicago, Ill.

1906. FOSTER, H. W. Steel Inspector, Bethlehem Steel Company, South Bethlehem, Pa.

1904. FOSTER, W. C. Vice-President and General Manager, Glamorgan Pipe and Foundry Company, Rutherford, N. J.

1905. FOX, ADAM H. President, American Equipment Company, Norristown, Pa.

1906. FRANK JEROME W. Chemist, Standard Varnish Works, 29 Broadway, New York, N. Y.

1898. FRANKLIN INSTITUTE. William H. Wahl, Secretary, 15 South Seventh Street, Philadelphia, Pa.

1907. FRANKLIN MANUFACTURING COMPANY, H. H. 400 South Geddes Street, Syracuse, N. Y.

1905. *FRAZIER, H. Consulting Engineer, Seaboard Air Line Railway, 812 American Bank Building, Richmond, Va.

1905. *FREEMAN, JOHN R. Consulting Engineer, 815 Barrigan Building, Providence, R. I.

1903. FRENCH, JAMES B. Bridge Engineer, The Long Island Railroad Company, Jamaica, N. Y.

1904. FROEHLING AND ROBERTSON. Analytical Chemists, Chemical and Mining Engineers, 17 South Twelfth Street, Richmond, Va.

1905. *FRY, LAWFORD H. Engineer of Tests, Baldwin Locomotive Works, 500 North Broad Street, Philadelphia, Pa.

ELECTED.

1907. FRYE, ALBERT I. Consulting Engineer, 210 Hawthorne Street, Brooklyn, N. Y.

1903. *FULLER, ALMON H. Professor of Civil Engineering, Washington University, University Station, Seattle, Wash.

1906. FULLER, CHARLES E. Associate Professor of Mechanical Engineering, Massachusetts Institute of Technology, Boston, Mass.

1904. FULLER, WM. B. Consulting Civil Engineer, 170 Broadway, New York, N. Y.

1905. *GAEHR, DAVID. 683 Gordon Avenue, Cleveland, O.

1903. GALBRAITH, J. Principal, School of Practical Science, Toronto, Can.

1905. GARFIELD, ALEXANDER STANLEY. Chief Engineer, Cie. Francaise Thomson-Houston; Consulting Engineer, Mediterranean Thomson-Houston Company and General Electric Company. 67 Avenue De Malakoff, Paris, France.

1905. GARLINGHOUSE, F. L. Structural Engineer, Jones and Laughlin Steel Company, Glenshaw, Pa.

1905. GAY, MARTIN. Assistant Engineer, Department of Bridges, New York City, 103 East One Hundred and Twenty-fifth Street, New York, N. Y.

1905. *GERLACH, O. General Superintendent, Iola Portland Cement Company, Iola, Kan.

1902. *GERSTELL, A. F. Vice-President and General Manager, Alpha Portland Cement Company, Alpha, N. J.

1906. *GIBBONEY, JAMES H. Chief Chemist, Norfolk and Western Railway Company, 342 Campbell Avenue, S. W., Roanoke, Va.

1902. GIBBS, A. W. General Superintendent of Motive Power, Pennsylvania Railroad, Altoona, Pa.

1902. *GIBBS, GEORGE. Chief Engineer of Electric Traction, Pennsylvania Tunnel and Terminal Railroad Company, 10 Bridge Street, New York, N. Y.

1905. GIESLER, ARTHUR. Consulting Engineer, 29 Broadway, New York, N. Y.

1905. GILBERT, H. GRAY. Assistant Engineer, Chief Engineer's Office, Louisville and Nashville Railroad, Louisville, Ky.

1907. GILG, HENRY F. Secretary, Refined Iron and Steel Company, 606 Lewis Building, Pittsburg, Pa.

ELECTED

1905. GILL, AUGUSTUS H. Assistant Professor of Technical Analysis, Massachusetts Institute of Technology, Boston, Mass.

1906. GILLESPIE, ARTHUR J. Representative, The Patterson, Sargent Company, 4929 Forrestville Avenue, Chicago, Ill.

1906. GINDER, WM. H. H. Chemist and Engineer of Tests, Eastern Steel Company, Pottsville, Schuylkill County, Pa.

1904. *GIROUX, GUSTAVE. Inspector of Materials, Canadian Pacific Railway Company, 1101 East Craig Street, Montreal, P. Q., Canada.

1904. *GLASGOW IRON COMPANY. C. B. Shoemaker, President, 603-608 Harrison Building, Philadelphia, Pa.

1904. *GODWIN, W. S. General Manager, American Block Press Company, 404 Temple Bar Building, Brooklyn, N. Y.

1904. GOODMAN, CARLTON M. Superintendent, Standard Portland Cement Company, Leeds, Ala.

1904. GOODSPEED, G. M. Meallurgist, National Tube Company, McKeesport, Pa.

1904. GOODWIN, H. S. Bridge Inspector, 201 North Owen Avenue, Lansdowne, Pa.

1907. GOSA, HERBERT O. Civil Engineer, 1124 Candler Building, Atlanta, Ga.

1907. GOSS, OLIVER P. M. Engineer of Timber Tests, United States Forest Service. *For Mail:* Post Office Box 112, University Station, Seattle, Wash.

1896. GOSS, WILLIAM, F. M. Dean of the Schools of Engineering, University of Illinois, Urbana, Ill.

1905. GOW, CHARLES R. Civil Engineer and Contractor, 79 Milk Street, Boston, Mass.

1904. GOWEN, CHARLES S. Engineer, New Croton Dam, Ossining, N. Y.

1906. *GRACE, S. P. Chief Engineer, Central District and Printing Telegraph Company, Pittsburg, Pa.

1903. GRANTHAM, HERBERT T. Chief Engineer, Belmont Iron Works, 1622 Real Estate Trust Building, Philadelphia, Pa.

1906. GRAY, JR., JOHN H. Chemist to the Board of Public Works, 2511 Sacramento Street, San Francisco, Cal.

1903. *GRAY, JOHN LATHROP. Assistant Superintendent, Tidewater Oil Company, East Twenty-second Street, Bayonne, N. J.

ELECTED.

1896. *GRAY, THOMAS. Professor of Dynamic Engineering, Rose Polytechnic Institute, Terre Haute, Ind.

1905. *GRAY, THOMAS TARVIN. Chemist, Tide Water Oil Company, East Twenty-second Street, Bayonne, N. J.

1906. GREEN, HERBERT. Mechanical Engineer, South Baltimore Steel Car and Foundry Company, Baltimore Md.

1906. GREENE, FREDERICK S. Vice-President and General Manager, The Waterproofing Company, 151 West Twenty-eighth Street, New York, N. Y.

1905. GREENE, GEO. W. Inspecting Engineer, American Bureau of Inspection and Tests, 313 Wabash Building, Pittsburg, Pa.

1904. *GREENMAN RUSSELL S. Assistant Engineer, State Engineer's Department, Albany, N. Y.

1907. GREFF, NORRIS B. President, Mound City Paint and Color Company, St. Louis, Mo.

1906. GREGORY, ED. D. Mill Manager, Frazer Paint Company, Bedford City, Va.

1906. GREGORY, JOHN H. Engineer in Charge, Improved Water and Sewage Works, Columbus, O.

1904. *GREGORY, W. B. Associate Professor of Experimental Engineering, Tulane University of Louisiana, New Orleans, La.

1902. GREINER, J. E. Assistant Chief Engineer, Baltimore and Ohio Railroad, Baltimore, Md.

1907. GRIESENAUER, GEORGE J. Inspector of Cement, Chicago, Milwaukee and St. Paul Railway Company, 194 Fullerton Avenue, Chicago, Ill.

1906. GRIFFITH, R. E. Vice-President, American Cement Company, 604 Pennsylvania Building, Philadelphia, Pa.

1906. *GRIFFITHS, T. S. General Manager, Canadian Inspection Company, St. James Street, Montreal, Can.

1905. GRISWOLD, R. E. Drain, Ore.

1906. GROSSMAN, EDMUND. Manager, Concrete Engineering and Supply Company, 1133 Broadway, New York, N. Y.

1907. GULICK, HENRY, JR. Engineers and Founders Laboratories, 439 Third Avenue, Pittsburg, Pa.

1906. *HADFIELD, R. A. Steel Manufacturer, Hecla Works, Sheffield, England.

1901. HAGAR, EDWARD M. Manager, Cement Department, Illinois Steel Company, 1060 The Rookery, Chicago, Ill.

ELECTED.

1907. HAGUE, CHESTER J. Constructing Engineer, Eastern Expanded Metal Company, 101 Tremont Street, Boston, Mass.

1906. HAINES, JOHN L. Chief of Order Department, Jones and Laughlin Steel Company, Pittsburg, Pa.

1905. HALDEMAN, HORACE L. Treasurer, Pulaski Iron Company, 1008 Real Estate Trust Building, Philadelphia, Pa.

1905. HALL, WILLIAM L. Assistant Forester, in Charge of Office of Forest Products, Bureau of Forestry, United States Department of Agriculture, Washington, D. C.

1903. *HALLETT, NELSON A. Cement Inspector, 1 Ashburton Place, Boston, Mass.

1906. HAM, WILLIAM H. Engineer, General Fireproofing Company, 156 Fifth Avenue, New York, N. Y.

1903. *HANCOCK, E. L. Assistant Professor of Applied Mechanics, Purdue University, Lafayette, Ind.

1905. *HAND, ELWOOD STOKES. Installation Engineer, Mississippi Wire Glass Company, 115 Broadway, New York, N. Y.

1905. HANNA, W. C. Chemist, California Portland Cement Company, Colton, Cal.

1905. HARDING, CHESTER. Captain, Corps of Engineers, United States Army, Gatun, Canal Zone.

1904. *HARDING, JAMES J. Engineer of Masonry Construction, Chicago, Milwaukee and St. Paul Railway, 1232 Railway Exchange Building, Chicago, Ill.

1902. HARDING, W. H. President, Coplay Cement Manufacturing Company, 517 Pennsylvania Building, Philadelphia, Pa.

1903. *HARGROVE, JULIAN O. Inspector of Asphalt and Cements, 1603 O Street, N. W., Washington, D. C.

1902. HARRIMAN, N. F. Chemist and Engineer of Tests, Union Pacific Railroad, Omaha, Neb.

1907. HARRIS, ALBERT W. Purchasing Agent, Laurentide Paper Company, Limited, Grand Mere, Quebec, Canada.

1905. HARRISON, ARTHUR B. Manager, Paint Department, Clifford L. Miller and Company, 125 East Twenty-third Street, New York, N. Y.

1902. *HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY. Francis B. Allen, Vice-President, Hartford, Conn.

ELECTED.

1904. HARTLEY, HENRY J. Superintendent, Boiler Department, William Cramp and Sons, 1624 Oxford Street, Philadelphia.

1898. HARTRANFT CEMENT COMPANY, WILLIAM G. Sole Selling Agent for Old Dominion and Phœnix Portland Cement, Real Estate Trust Building, Philadelphia, Pa.

1905. *HARVARD COLLEGE LIBRARY. Alfred C. Potter, Assistant Librarian, Cambridge, Mass.

1898. *HATT, WILLIAM K. Professor of Applied Mechanics, Purdue University, Lafayette, Ind.

1904. HAWXHURST, ROBERT. Consulting Engineer, 10 Austin Friars, London, E. C., England. *For Mail:* General Manager, Poduosa Mining Company, Care Anglo South American Bank, Antofagasta, Chile.

1906. HAYES, J. ARTHUR. Resident Manager, United States Cast Iron Pipe and Foundry Company, Burlington, N. J.

1904. *HAYES, HAMMOND V. Engineer, American Telephone and Telegraph Company, 125 Milk Street, Boston, Mass.

1907. HAYWARD, HENRY E. Engineer of Tests, Link-Belt Company, Nicetown, Philadelphia, Pa.

1906. *HAYWARD, H. W. Instructor, Mechanical Engineering, Massachusetts Institute of Technology, Boston, Mass.

1906. HAZARD MANUFACTURING COMPANY. John C. Bridgman, General Manager, Wilkesbarre, Pa.

1907. HAZEN, WILLIAM NELSON. Engineer, Expanded Metal Engineering Company, 225 Fifth Avenue, New York, N. Y.

1906. HEALD, E. C. Chief Structural Engineer, Office of Supervising Architect, Treasury Department, Washington, D. C.

1903. HEARNE, W. W. Member of firm Mathew Addy and Company, 1625 Real Estate Trust Building, Philadelphia, Pa.

1905. HECKEL, G. B. Editor, *Drugs, Oils and Paints*, 634–36 The Bourse, Philadelphia, Pa.

1904. HEIDENREICH, E. LEE. Consulting Engineer, General Supply and Construction Company, Room 1202, 335 Madison Avenue, New York, N. Y.

1904. *HELWIG, ALFRED. Engineer, Edison Electric Illuminating Company, 360 Pearl Street, Brooklyn, N. Y.

1904. *HEMSTREET, GEORGE P. Superintendent, Hastings Pavement Company, Hastings-on-Hudson, N. Y.

ELECTED.

1903. HENSHAW, JOHN O. Member, N. S. Bartlett and Company, 126 State Street, Boston, Mass.

1904. *HERING, RUDOLPH. Hydraulic and Sanitary Engineer, 170 Broadway, New York, N. Y.

1906. HERNDON, EDWARD L. Treasurer, The Eastern Steel Company, Pottsville, Pa.

1906. *HERSEY, MILTON L. City and Provincial Analyst, 171 St. James Street, Montreal, Canada.

1902. HILDRETH, P. S. Consulting and Inspecting Engineer, 32 Broadway, New York, N. Y.

1907. HINCKLEY, BENJAMIN S. Engineer of Tests, New York, New Haven and Hartford Railroad Company, New Haven, Conn.

1907. HINCKLEY, J. F. Chief Engineer, St. Louis and San Francisco Railroad Company, St. Louis, Mo.

1905. HITCHCOCK, F. C. Engineer, Contractor and Manufacturer, New York, N. Y.

1906. HOBBS, F. E. Major, Ordnance Department, U. S. Army, Watertown Arsenal, Watertown, Mass.

1904. *HOFF, OLAF. Vice-President, Butler Brothers Construction Company, 1170 Broadway, New York, N. Y.

1907. HOFFHINE, JOHN. First Assistant Chemist, Union Pacific Railroad, Lock Box, 273 Omaha, Neb.

1902. HOFMAN, H. O. Professor of Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

1907. *HOKANSON, MARTIN. Assistant Professor of Materials of Construction, Carnegie Technical Schools, Pittsburg, Pa.

1906. *HOLMES, ADDISON F. Instructor, Mechanical Engineering, Massachusetts Institute of Technology, Boston, Mass.

1903. HOLMES, JOSEPH A. State Geologist of North Carolina, Chapel Hill, N. C.

1906. *HOOKER, A. H. Chief Chemist, The Heath and Milligan Manufacturing Company, 90 Seward Street, Chicago, Ill.

1904. HOPTON, W. E. Assistant Purchasing Engineer, Solvay Process Company, Syracuse, N. Y.

1904. HOW, R. W. Chief Inspector, Bridge Engineer's Office, Long Island Railroad Company, 5 Hanson Place, Brooklyn, N. Y.

1906. HOWARD, JAMES E. Watertown Arsenal, Watertown, Mass.

ELECTED.

1903. HOWARD, L. E. Superintendent, Simonds Manufacturing Company, Seventeenth Street and Western Avenue, Chicago, Ill.

1896. *HOWE, HENRY M. (*Past-President*). Professor of Metallurgy, Columbia University, 27 West Seventy-third Street, New York, N. Y.

1904. *HUBBELL, C. A. President, R. Almond Manufacturing Company, Brooklyn, N. Y.

1904. HUBER, FREDERICK W. Engineer of Tests, United States Geological Survey, 1210 James Flood Building, San Francisco, Cal.

1905. *HUDSON, H. N. General Manager, Hoyt Metal Company, St. Louis, Mo.

1906. HUGHES, E. A. Secretary, Moorhead Brother and Company, Sharpsburg, Pa.

1905. *HUGHES, HECTOR J. Assistant Professor of Hydraulics and Sanitary Engineering, Harvard University, 114 Pierce Hall, Cambridge, Mass.

1905. HUGHES AND PATTERSON. Manufacturers of Bar Iron, 800 Richmond Street, Philadelphia, Pa.

1907. HUGHES, L. S. Chief Chemist, Picher Lead Company, Joplin, Mo.

1905. HULL, WALTER A. General Manager, Shawmut Clay Manufacturing Company, Drummond, Pa.

1904. HUME, A. P. Engineer of Tests, American Bridge Company, Pencoyd, Pa.

1896. *HUMPHREY, RICHARD L. Consulting Engineer and Chemist, 1001 Harrison Building, Philadelphia, Pa.

1906. HUMPTON, WM. G. Engineer of Tests, Cambria Steel Company, Riverview, Johnstown, Pa.

1903. HUNNINGS, S. V. Chief Chemist, American Locomotive Company, Schenectady, N. Y.

1905. HUNT, H. B. General Inspector, American Locomotive Company, Schenectady, N. Y.

1903. *HUNT, LOREN E. Civil Engineer, United States Forest Service, Berkeley, Cal.

1899. *HUNT COMPANY, ROBERT W. Inspecting and Testing Engineers, 1121 The Rookery, Chicago, Ill.

1905. HUNTER, JOHN ANDREW. Assistant Professor of Mechanical Engineering, University of Colorado, Boulder, Colo.

ELECTED.

1903. HUNTER, JOSEPH W. Engineer and Surveyor, State Highway Commissioner, Harrisburg, Pa.

1906. HUTCHINSON, CARY T. Consulting Engineer, 60 Wall Street, New York, N. Y.

1904. HUTCHINSON, GEORGE W. Engineer of Tests, Old Dominion Iron and Nail Works, Richmond, Va.

1905. HYDE, A. LINCOLN. Assistant Professor of Bridge Engineering, University of Missouri, Columbia, Mo.

1903. HYDE, CHARLES G. Assistant Professor of Sanitary Engineering, University of California, Berkeley, Cal.

1907. IBACH, B. FRANK. Superintendent, Bridge and Structural Department, The Eastern Steel Company, Pottsville, Pa.

1906. ICKES, ELWOOD T. Inspector, Carnegie Steel Company, Room 522, Carnegie Building, Pittsburg, Pa.

1904. *†ILLINOIS CENTRAL RAILROAD COMPANY, J. T. Harahan, Engineer, Commercial National Bank Building, Chicago, Ill.

1900. †ILLINOIS STEEL COMPANY. P. E. Carhart, Inspecting Engineer, Rookery Building, Chicago, Ill.

1906. INGALLS, F. P. Chemist, John W. Masury and Son, 1329 Fiftieth Street, Brooklyn, N. Y.

1903. INSURANCE ENGINEERING. Franklin Webster, Editor, 120 Liberty Street, New York, N. Y.

1902. INTERNATIONAL ACHESON GRAPHITE COMPANY. Manufacturers of Graphite and Graphite Articles, Niagara Falls, N. Y.

1904. INTERNATIONAL HARVESTER COMPANY. John G. Wood, Second Assistant Manager, Manufacturing Department, 7 Monroe Street, Chicago, Ill.

1902. IRON TRADE REVIEW, THE. Robert T. Kent, Editor, Cleveland, O.

1907. JACKSON, M. R. Vice-President and General Manager, Schoen Steel Wheel Company, P. O. Box 1212, Pittsburg, Pa.

1907. JAMES H. L. Superintendent, Roll Department, Pencoyd Iron Works, Pencoyd, Pa. *For Mail:* 2000 North Park Avenue, Philadelphia, Pa.

1896. JARECKI, ALEXANDER. Superintendent, Jarecki Manufacturing Company, Limited, Erie, Pa.

ELECTED.

1905. Jeffers, John M. Oil Inspector, National Tube Company, 1603 Jenny Lind Street, McKeesport, Pa.

1897. Jenkins, John. General Manager, Milton Iron Company Milton, Pa.

1904. Jennings, Arthur S. Editor, *The Decorator*, 365 Birkbeck Bank Chambers, High Holborn, London, W. C., England.

1906. Jennings, Bertrand F. Manager, Hudson Portland Cement Company, 161 Devonshire Street, Boston, Mass.

1900. *Jewett, J. Y. Cement Expert, United States Reclamation Service, Armour Institute of Technology, Chicago, Ill.

1900. Job, Robert, Member of firm Booth, Garrett and Blair, 406 Locust Street, Philadelphia, Pa.

1903. *Johnson, Albert L. Chief Engineer, Expanded Metal Fire-proofing Company, 606 Century Building, St. Louis, Mo.

1903. Johnson, Arthur N. State Highway Engineer, Springfield, Ill.

1904. Johnson, Charles C. Chemist, Standard Explosives Company, Ltd., Vandreuil Station, Quebec, Canada.

1905. *Johnson, Edmund. Cement Chemist, Yankton, S. Dak.

1904. Johnson, J. S. A. Professor of Experimental Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

1904. Johnson, Lewis J Professor of Civil Engineering Harvard University, 309 Pierce Hall, Cambridge, Mass.

1904. Johnson, W. Martin. Vice-President, The Schoen Steel Wheel Company, 312 South Fifteenth Street, Philadelphia, Pa.

1906. Johnston, W. C. Manager, Iron Mill, Monongahela Iron and Steel Company, Post Office Box 215, Pittsburg, Pa.

1906. Johnston, William A. Associate Professor of Mechanical Engineering, Massachusetts Institute of Technology, Boston, Mass.

1905. *Jones, C. R. Professor of Mechanical Engineering, West Virginia University, Morgantown, W. Va.

1902. *Jones and Laughlin Steel Company. Steel Manufacturers; Willis L. King, Vice-President, Pittsburg, Pa.

1907. Jordahl, Anders. Concrete and Structural Engineer, W. S. Barstow and Company, 50 Pine Street, New York, N. Y.

ELECTED.

1903. JORDAN, WILLIAM, JR. Structural Materials Testing Laboratory, U. S. Geological Survey, St. Louis, Mo.

1906. KAFKA, FRED P. General Fireproofing Company, 156 Fifth Avenue, New York, N. Y.

1906. KANSKI, ROMAN P. Topographical Draughtsman, Office of President of Borough of Bronx, 607 Union Avenue, New York, N. Y.

1904. KASSON, HENRY R. District Manager, Barber Asphalt Paving Company, 1236 Stock Exchange Building, Chicago, Ill.

1906. *KAUFMAN, GUSTAVE. Chief Engineer, The Wilson and Baillie Manufacturing Company, 26 Court Street, Brooklyn, N. Y.

1907. KAVANAUGH, WILLIAM H. Professor of Experimental Engineering, University of Minnesota, Minneapolis, Minn.

1904. *KAY, EDGAR B. Professor of Engineering, University of Alabama, University Post Office, Ala.

1907. KAYLOR, JOHN J. Mechanical Inspector, Harriman Lines, 5 Sipe Street, Allegheny City, Pa.

1906. KEARNS, W. F. 161 Devonshire Street, Boston, Mass.

1903. KEAY, H. O. Assistant Professor of Mechanical Engineering, McGill University, Montreal, Canada.

1906. KELLOGG, R. S. Forest Assistant, Forest Service, Washington, D. C.

1899. KENNEDY, FRANK G., JR. 408 North American Building, Philadelphia, Pa.

1904. *KENNEDY, JEREMIAH J. Consulting Engineer, 52 Broadway, New York, N. Y.

1904. KENNEY, E. F. Metallurgical Engineer, Cambria Steel Company, Johnstown, Pa.

1906. KENNEY, LEWIS HOBART. Draftsman in Charge Department of Steam Engineering, U. S. Navy, Navy Yard, League Island, Pa. *For Mail:* 4226 Girard Avenue, Philadelphia, Pa.

1902. KENT, WILLIAM. Professor of Mechanical Engineering, and Dean of the L. C. Smith College of Applied Science, Syracuse University, Syracuse, N. Y.

1904. KENYON, CLARENCE A. President, Hoosier Construction Company and Granite Bituminous Paving Company, Indianapolis, Ind.

ELECTED.

1905. KETCHUM, MILO S. Professor of Civil Engineering, University of Colorado, Boulder, Colo.

1907. KIEFER, H. E. Chemist, Edison Portland Cement Company, Stewartsville, N. J.

1903. KIESEL, W. F., JR. Assistant Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1906. *KIMMEL, H. R. Chemist; Studebaker Brothers Manufacturing Company, The Duey—D, South Bend, Ind.

1905. KING, W. GRANT. Manager, Iroquois Iron Works, 178 Walden Avenue, Buffalo, N. Y.

1899. *KING, WILLIS L. Vice-President, Jones and Laughlin Steel Company, Pittsburg, Pa.

1899. *KINKEAD, J. A. Engineer of Tests, American Locomotive Company, Schenectady, N. Y.

1902. *KIRCHHOFF, C. Editor, *The Iron Age*, 14 Park Place, New York, N, Y.

1903. *KIRCHNER, PAUL A. Structural Engineer, The Millbrook Company, 37 Wall Street, New York, N. Y.

1903. *KITTREDGE, H. G. Secretary, The Kay and Ess Company, Dayton, O.

1907. KLINGER, W. J. The Kay and Ess Company, 328 Edgewood Avenue, Dayton, O.

1907. KNAPP, JOSEPH B. Engineer of Timber Tests, United States Forest Service, Eugene, Ore.

1904. KNIGHT, FRANK B. Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

1903. *KNIGHTON, J. A. Engineer in Charge of Construction, Blackwells Island Bridge, 56 Sutton Place, New York, N. Y.

1904. KNOWLES, MORRIS. Chief Engineer, Bureau of Filtration, Pittsburg, Pa.

1903. KOHR, D. A. Chemist, Lowe Brothers, Dayton, O.

1906. KRANZ, W. G. Superintendent, Steel Casting Works, Sharon, Pa.

1896. *KREUZPOINTNER, PAUL. Pennsylvania Railroad, Altoona, Pa.

1904. KRUPP COMPANY, FRIED. Emil Ehrensberger, Director, Essen, Germany.

1907. KULP, SAMUEL RANDALL. Assistant Chemist, Bethlehem Steel Company, 17 South Howard Street, Allentown, Pa.

1904. KUMMER, FREDERIC A. General Manager, United States Wood Preserving Company, 29 Broadway, New York, N. Y.

ELECTED.

1903. LA CHICOTTE, H. A. Engineer in Charge, Manhattan Bridge (No. 3) and Blackwell's Island Bridge (No. 4), Park Row Building, New York, N. Y.

1905. *LACKAWANNA STEEL COMPANY. Franklin E. Abbott, Inspecting Engineer, Buffalo, N. Y.

1906. LANE, ALFRED M. General Superintendent, Mauran, Russell and Garden, 1620 Chemical Building, St. Louis, Mo.

1906. LANE, H. C. Chief Draftsman, Maryland Steel Company, Sparrows Point, Md.

1903. *LANE, HENRY M. 1137 Scofield Building, Cleveland, O.

1907. LANSINGH, V. R. Illuminating Engineer, General Manager, Hotophane Company, 227 Fulton Street, New York, N. Y.

1899. *LANZA, GAETANO. Professor Theoretical and Applied Mechanics, in charge Mechanical Engineering Department, Massachusetts Institute of Technology, Boston, Mass.

1904. *LARNED, E. S. Manager, United Building Materials Company, 101 Milk Street, Boston, Mass.

1903. LARSSON, C. G. E. Assistant Chief Engineer, American Bridge Company, 42 Broadway, New York, N. Y.

1907. LAWSON, THOMAS R. Associate Professor of Rational and Technical Mechanics, Rensselaer Polytechnic Institute, 99 Twelfth Street, Troy, N. Y.

1903. LAYMAN, W. A. General Manager, Wagner Electrical Manufacturing Company, 2017 Locust Street, St. Louis, Mo.

1906. LEIDEL, HENRY. Factory Superintendent, Banzai Manufacturing Company, 122 Green Street, Greenpoint, Brooklyn, N. Y.

1904. *LEMEN, W. W. Engineer of Tests, Norfolk and Western Railway, Roanoke, Va.

1906. LESCHEN, HARRY J. Engineer, Tramway Department, A. Leschen and Sons Rope Company, 920 North First Street, St. Louis, Mo.

1898. *†LESLEY, R. W. (*Vice-President*). President, American Cement Company, Pennsylvania Building, Philadelphia, Pa.

1907. *LEWIS, E. SIDNEY. Standard Steel Works, 1103 Harrison Building, Philadelphia, Pa.

1906. LEWIS, FRANK D. District Representative, Robert W. Hunt and Company, West Fourth Avenue, Phœnixville, Pa.

ELECTED.

1903. LEWIS, FREDERICK H. Consulting Engineer, Leeds, Jefferson County, Ala.

1906. LEWIS, GEORGE T. Secretary and Treasurer, Monongahela Iron and Steel Company, Post Office Box 215, Pittsburg, Pa.

1905. LEWIS, JOHN F. Chief Inspector, Duquesne Steel Works, Carnegie Steel Company, Duquesne, Pa.

1907. LEWIS, RANSOME V. Manager Elmira Plant, Empire Bridge Company, 412 West Clinton Street, Elmira, N. Y.

1907. LEYSHON, T. A. Civil and Mining Engineer, Olmsted, Va.

1904. *LIDGERWOOD, JOHN H., JR. Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

1905. *LIMA LOCOMOTIVE AND MACHINE COMPANY, THE. W. H. Agerter, Secretary and Treasurer, Lima, O.

1896. LINDENTHAL, GUSTAV. Consulting Engineer, 45 Cedar Street, New York, N. Y.

1906. LINTON, H. H. Salesman, Fuller Brothers and Company, 139 Greenwich Street, New York, N. Y.

1903. *LITTLE, A. D. Chemical Expert and Engineer, 93 Broad Street, Boston Mass.

1905. LLOYD, JOHN. Banker and Coal Operator, Altoona, Pa.

1903. LOBDELL, W. W. President, Lobdell Car-Wheel Company, Wilmington, Del.

1902. LOBER, J. B. President, Vulcanite Portland Cement Company, Land Title Building, Philadelphia, Pa.

1904. LOBER, W. H. Inspector General, Barber Asphalt Paving Company, Rialto Building, San Francisco, Cal.

1905. *LOHMANN, H. W. Manager, James Stewart and Company, Engineers and Contractors, 302 Lincoln Trust Building, St. Louis, Mo.

1905. LONG, E. MCLEAN. Civil Engineer, Inspector of Steel, 220 Broadway, New York, N. Y.

1904. *LONG, R. A. President and General Manager, The Long-Bell Lumber Company, Keith and Perry Building, Kansas City, Mo.

1904. LONG, WILLIAM. Engineer of Tests, Bureau of Engraving and Printing, 2133 K Street, N., Washington, D. C.

1906. LOOS, EDWARD A. Chemist, 27 Elizabeth Street, Auburn, N. Y.

1907. LORD, RICHARD C. Engineer of Tests, Louisville and Nashville Railroad Company, South Louisville, Ky.

ELECTED.

1903. LORDLY, HENRY ROBERTSON. Engineer in Charge, Lachine Canal, Blacks Bridge, Montreal, Canada.

1903. LOUDON, ARCH. M. Foundryman, Elmira, N. Y.

1902. LOVELL, EARL B. Adjunct Professor of Civil Engineering, Columbia University, 235 West One Hundred and Second Street, New York, N. Y.

1906. LOW, WILSON H. Head Chemist, The Cudahy Packing Company, South Omaha, Neb.

1899. LOWE BROTHERS. Paint and Color Makers; Houston Lowe, Vice-President, Dayton, O.

1900. LOWETH, CHARLES F. Engineer and Superintendent of Bridges and Buildings, Chicago, Milwaukee and St. Paul Railway, 1232 Railway Exchange, Chicago, Ill.

1907. *LOWTHER, BURTON. Testing Engineer, Kansas City Chemic-Technic Laboratories Company, 804 Locust Street, Kansas City, Mo.

1905. LUCAS AND COMPANY. John W. Irving Lewis, Consulting and Contracting Representative, 322–330 Race Street, Philadelphia.

1904. LUDLOW, S. H. Chemist, Empire Portland Cement Company, Warner, N. Y.

1905. LUKENS, ALAN N. Mechanical Engineer, Railway Steel Spring Company, 71 Broadway, New York, N. Y.

1902. *LUKENS IRON AND STEEL COMPANY. Charles L. Huston, Vice-President, Coatesville, Pa.

1906. LUM, D. W. Chief Engineer, Maintenance of Way, Southern Railway Company, Washington, D. C.

1898. *LUNDTEIGEN, ANDREAS. Chemist, Union City, Mich.

1906. LYNCH, THOMAS. President, H. C. Frick Coke Company, Carnegie Building, Pittsburg, Pa.

1902. LYNCH, T. D. Engineer of Material Tests, Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa.

1902. MACPHERRAN, R. S. Chemist, J. I. Case Threshing Machine Company, Racine, Wis.

1896. MCCAULEY, H. K. Secretary and Treasurer, Altoona Iron Company, Altoona, Pa.

1907. MCCAUSTLAND, E. J. Professor of Mining Engineering, University of Alabama, Tuscaloosa, Ala.

1907. *MCCLEARY, E. T. Chief Chemist, Youngstown Sheet and Tube Company, Youngstown, O.

ELECTED.

1906. McCORMACK, HARRY M. Associate Professor of Metallurgy, Armour Institute, Chicago, Ill.

1907. *McCOURT, W. E. Head of Department of Geology, Washington University, Saint Louis, Mo.

1905. McCREA, ARCHIBALD M. President, Union Spring and Manufacturing Company, Farmers' Bank Building, Pittsburg, Pa.

1903. *McCREADY, ERNEST B. General Manager Lehigh Valley Testing Laboratory, Fourth and Linden Streets, Allentown, Pa.

1907. *McFARLAND, G. S. Chemist, Gordon, Wyman and Company, Worcester, Mass.

1906. McFARLAND, J. A. Chemist, Missouri Pacific Railway, St. Louis, Mo.

1905. McGRADY, J. W. Chief Inspector, Homestead Steel Works, Carnegie Steel Company, Munhall, Pa.

1907. McGUIRE, JAMES C. Civil Engineer, 26 Cortlandt Street, New York, N. Y.

1906. McILHINEY, PARKER C. Consulting Chemist, 145 East Twenty-third Street, New York, N. Y.

1896. *McKENNA, CHARLES F. Chemist, 221 Pearl Street, New York, N. Y.

1905. McKIBBEN, FRANK P. Professor of Civil Engineering, Lehigh University, South Bethlehem, Pa.

1904. McLEAN, E. Foreman, Wheel Foundry, Pennsylvania Railroad, Altoona, Pa.

1902. *†McLEOD, JOHN (*Member of Executive Committee*). 1108 Pennsylvania Building, Philadelphia, Pa.

1904. *McNAUGHER, D. W. Civil Engineer, Monongahela Bank Building, Pittsburg, Pa.

1907. McNAUGHTON, J. P. General Sales Agent, Dominion Iron and Steel Company, Sydney, Nova Scotia, Can.

1904. *MACK, J. LATHROP. Chemist, Nazareth Cement Company, Nazareth, Pa.

1895. *MACLAY, WILLIAM W. President, Glens Falls Portland Cement Company, Glens Falls, N. Y.

1906. MACLEAN, ALEX. J. Professor of Naval Architecture, Webb Academy, Fordham Heights, New York, N. Y.

1904. MAHON, R. W. Chemist, New York Central and Hudson River Railroad, West Albany, N. Y.

1907. MAIN, WILLIAM. Consulting Engineer and Chemist, 100 Broadway, New York, N. Y.

ELECTED.

1902. MAJOR, CHARLES. President, A. and P. Roberts Company; Manager, Pencoyd Iron Works, Pencoyd, Pa.

1907. MANSFIELD, ARTHUR N. Engineering Department, American Telephone and Telegraph Company, 15 Dey Street, New York, N. Y.

1898. *MARBURG, EDGAR (*Secretary-Treasurer*). Professor of Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

1906. MARIS, JOHN M. Principal, School of Structural Engineering, International Correspondence Schools, Scranton, Pa.

1905. *MARQUETTE CEMENT MANUFACTURING COMPANY. T. G. Dickinson, General Manager, La Salle, Ill.

1907. MARSH, E. P. Assistant to Engineer of Structures, New York Central and Hudson River Railroad, Room 1201, 335 Madison Avenue, New York, N. Y.

1906. MARSHALL, S. M. Assistant Chief Engineer, Cambria Steel Company, Johnstown, Pa.

1906. MARSHALL, WILLIAM. President, The Anglo-American Varnish Company, 53 Johnson Street, Newark, N. J.

1905. MARSTEN, A. Dean of Division of Engineering, Iowa State College, Ames, Iowa.

1907. MARTIN, EDGAR D. Architect, 172 Washington Street, Chicago, Ill.

1902. MARTIN, SIMON S. Superintendent, Maryland Steel Company, Sparrows Point, Md.

1907. MARVIN, F. O. Dean, School of Engineering, University of Kansas, Lawrence, Kan.

1903. MASTERS, J. B. Inspecting Engineer, Pittsburg Representative of Hildreth and Company, 506 North St. Clair Street, Pittsburg, Pa.

1906. MASURY AND SON, JOHN W. 44 Jay Street, Brooklyn, N. Y.

1902. MATCHAM, CHARLES A. Manager, Lehigh Portland Cement Company, Allentown, Pa.

1903. MATHEWS, JOHN A. Assistant Engineer, Sanderson Works, Crucible Steel Company of America, Syracuse, N. Y.

1904. *MAURER, E. R. Professor of Mechanics, University of Wisconsin, Madison, Wis.

1904. *MEAD, CHARLES ADRIANCE. Principal Assistant to Boller and Hodge, Engineers, New York, N. Y., 165 Wildwood Avenue, Upper Montclair, N. J.

1899. MEADE RICHARD K. Chemist, Dexter Portland Cement Company, Nazareth, Pa.

ELECTED.

1905. MEANS, E. C. General Manager, The Low Moor Iron Company of Virginia, Low Moor, Va.

1902. MEIER, E. D. President and Chief Engineer, Herne Safety Boiler Company, 11 Broadway, New York, N. Y.

1895. *MERRIMAN, MANSFIELD (*Past President*). Consulting Engineer, 45 Broadway, New York, N. Y.

1907. *METALLURGICAL LABORATORY, THE. C. B. Murray, President, 611 Bailey-Farrell Building, Pittsburg, Pa.

1903. METCALF, WILLIAM. Braeburn Steel Company, Braeburn, Pa.

1906. MICHAEL, LOUIS G. Chemist, Iowa Agricultural Experiment Station, Ames, Iowa.

1905. MILLER, H. C. Specialist in Steel Concrete Construction, 1 Madison Avenue, New York, N. Y.

1903. MILLER, JOHN S., JR. Assistant Chemist, Supervising Architect's Office, Treasury Department, Washington, D. C.

1903. MILLER, RUDOLPH P. Consulting Engineer, 527 Fifth Avenue, New York, N. Y.

1900. MILLS, CHARLES M. Principal Assistant Engineer, Subway and Elevated Railroad Construction, Philadelphia Rapid Transit Company, Philadelphia, Pa.

1907. MITCHELL, A. E. Expert and Engineer of Tests, New York, New Haven and Hartford Railroad, 12 St. Ronan's Terrace, New Haven, Conn.

1903. MITCHELL, ARTHUR M. Secretary, The Eureka Chemical Company, 5 Howard Street, Newark, N. J.

1904. MITCHELL, A. S. Analytical Chemist, 220 Greenbush Street, Milwaukee, Wis.

1903. MITCHELL, JOSEPH. With John Williams Bronze and Iron Works, 556 West Twenty-seventh Street, New York City, N. Y.

1907. MITCHELL, ROBERT. General Sales Agent, Pennsylvania, Beech Creek and Eastern Coal Company, Land Title Building, Philadelphia, Pa.

1904. MIX, CHARLES DORF. Steel Merchant, 102 Purchase Street, Boston, Mass.

1905. MOECHEL, J. ROBT. Kansas City Chemic-Technic Laboratories, 3511 Woodland Avenue, Kansas City, Mo.

1903. *MOISSEFF, LEON S. Assistant Engineer to Commissioner of Bridges, 13 Park Row, New York, N. Y.

1896. *MOLDENKE, RICHARD. Metallurgist, Consulting Engineer, Watchung, N. J.

ELECTED.

1906. MONAGHAN, FRANK P. Chemist, Alpena Portland Cement Company, Alpena, Mich.

1906. MONTANA COLLEGE OF AGRICULTURE AND MECHANIC ARTS, Bozeman, Mont.

1903. MOORE, HERBERT F. Assistant Professor of Theoretic and Applied Mechanics, University of Illinois, 710 Hill Street, Champain, Ill.

1906. MOORE, JOHN N. Representative, The Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1905. MOORE, LEE C. Consulting Mechanical Engineer, 908 House Building, Pittsburg, Pa.

1902. MOORE, WILLIAM HARLEY. Engineer of Bridges, New York, New Haven and Hartford Railroad, New Haven, Conn.

1905. MORGAN CONSTRUCTION COMPANY. Victor E. Edwards, Mechanical Engineer, Worcester, Mass.

1905. *MORRISON, HUGH S. Mechanical Engineer, Mutual Assurance Society Building, Richmond, Va.

1905. MORROW, JAY J. Captain, Corps of Engineers, United States Army, Assistant to Engineers Commissioner, District of Columbia, District Building, Washington, D. C.

1905. MORSE, EDWIN KIRTLAND. Civil Engineer, 1801 Commonwealth Building, Pittsburg, Pa.

1904. MOSELEY, ALEX. W. Professor of Applied Mechanics, Lewis Institute, Chicago, Ill.

1907. MOTION, JAMES. Town Engineer of Selkirk, Selkirk, Manitoba, Canada.

1907. MOTION, JOHN. Chemist, Valvoline Oil Company, Edgewater, N. J.

1906. MOULTON, MACE. Consulting Engineer, 150 Nassau Street, New York, N. Y.

1904. †MUDGE, H. U. Second Vice-President, Chicago, Rock Island and Pacific Railway Company, La Salle Street Station, Chicago, Ill.

1899. *MUESER, WILLIAM. Civil Engineer; Member, Concrete Steel Engineering Company, 13–21 Park Row Building, New York, N. Y.

1903. MUNROE, CHARLES EDWARD. Head Professor of Chemistry, George Washington University, Washington, D. C.

1904. MUNSELL, A. W. Inspector of Materials, Detroit River Tunnel Company, Detroit, Mich.

ELECTED.

1899. MUTUAL BOILER INSURANCE COMPANY. 31 Milk Street, Boston, Mass.

1905. *MYERS, JR., E. T. D. Civil Engineer, Mutual Assurance Society Building, Richmond, Va.

1904. NAEGELEY, JOHN C. Engineer and Architect, 102 Richmond Avenue, Buffalo, N. Y.

1905. NATIONAL FIRE PROOFING COMPANY. E. V. Johnson, Vice-President and Western Manager, 806 Hartford Building, Chicago, Ill.

1900. NATIONAL TUBE COMPANY. Frank N. Speller, Metallurgical Engineer, Frick Building, Pittsburg, Pa.

1907. NEAL, THOMAS. Secretary and General Manager, Acme White Lead and Color Works, Detroit, Mich.

1902. *NEFF, F. H. Professor of Civil Engineering, Case School of Applied Science, Cleveland, O.

1904. NEILSON, GEORGE HARRISON. General Manager, Braeburn Steel Company, Braeburn, Pa.

1904. *NELSON, E. D. Engineer of Tests, Pennsylvania Railroad Company, Altoona, Pa.

1906. NETTLETON, W. A. General Superintendent, Motive Power, Frisco System, 1133 Frisco Building, St. Louis, Mo.

1902. NEW YORK AIR BRAKE COMPANY, THE. R. C. Augur, Mechanical Engineer, Watertown, N. Y.

1904. NEW YORK FIRE INSURANCE EXCHANGE. Henry E. Hess, Manager, 32 Nassau Street, New York, N. Y.

1898. *NEWBERRY, SPENCER B. Manager, Sandusky Portland Cement Company, Sandusky, O.

1905. NEWELL, F. H. Chief Engineer, United States Reclamation Service, 1330 F Street, Washington, D. C.

1906. *NICHOLSON, EDWARD E. Assistant Professor of Chemistry, University of Minnesota, Minneapolis, Minn.

1907. NIMMO, J. V. Resident Engineer, Atlantic, Quebec and Western Railway Company, Paspebiac, Que.

1906. *NIINA, YEIICHI. Cement Chemist, Syracuse, Ind.

1902. NORRIS, GEORGE L. Chemist, Standard Steel Works, Burnham, Pa.

1903. NORTON, C. L. Assistant Professor of Heat Measurement, Massachusetts Institute of Technology, Boston, Mass.

1906. *NOYES, WILLIAM A. Chemist, Bureau of Standards, Washington, D. C.

ELECTED.

1906. O'CONNER, B. F. Secretary and Treasurer, The Seaboard Paint Company, 3 Washington Avenue, Brooklyn, N. Y.

1898. OLSEN, TINIUS. Tinius Olsen and Company, Testing Machines, 500 North Twelfth Street, Philadelphia, Pa.

1902. ONDERDONK, J. R. Engineer of Tests, Baltimore and Ohio Railroad, Mt. Clare, Baltimore, Md.

1903. ORFORD COPPER COMPANY. 43 Exchange Place, New York, N. Y.

1902. ORTON, EDWARD, JR. Dean, College of Engineering, Ohio State University, and State Geologist of Ohio, Columbus, O.

1898. OSBORN ENGINEERING COMPANY, THE. Frank C. Osborn, Cleveland, O.

1907. OSBORNE, RAYMOND GAYLORD. Inspector of Cement, 401 West Twenty-third Street, Los Angeles, Cal.

1903. *OSTROM, JOHN N. Bridge Engineer, 1518 Farmers' Bank Building, Pittsburg, Pa.

1904. *OTIS, SPENCER. Mechanical Engineer, 1707 Railway Exchange Building, Chicago, Ill.

1902. OUTERBRIDGE, ALEX. E., JR. Chemist and Metallurgist, 1600 Hamilton Street, Philadelphia, Pa.

1904. *OWEN, JAMES. Civil Engineer, 196 Market Street, Newark, N. J.

1903. PAGE, LOGAN WALLER. Chief of Road Material Laboratory, United States Department of Agriculture, Washington, D. C.

1906. *PARKS, W. M. Commander, United States Navy, Bureau of Steam Engineering, Washington, D. C.

1906. PASCHKE, HERBERT. Waterproofing Specialist, Maplewood, N. J.

1906. PATTON, LUDINGTON. Secretary-Treasurer, Patton Paint Company, Milwaukee, Wis.

1906. PAYNE, HENRY. Professor of Engineering, South African College, Capetown, South Africa.

1904. PEARSON, HENRY. Vice-President and General Manager, Wason Manufacturing Company, Brightwood, Mass.

1896. PEASE, F. N. Assistant Chemist, Pennsylvania Railroad, 345 East Thirty-third Street, New York, N. Y.

1903. PECKITT, LEONARD. President, Empire Steel and Iron Company, Catasauqua, Pa.

ELECTED.

1904. PEEBLES, JOHN. Factory Superintendent, J. I. Case Threshing Machine Company, 712 Lake Avenue, Racine Wis.

1902. †PENNSYLVANIA STEEL COMPANY, THE. J. V. W. Reynders, Vice-President, Steelton, Pa.

1906. PEPPEL, S. V. Chemical Engineer, 1528 North High Street, Columbus, Ohio.

1907. PERRY, R. S. President, Harrison Brother and Company, Incorporated, Philadelphia, Pa.

1904. PERLEY, GEORGE E. Cement Expert, Department of Public Works, Ottawa, Canada.

1905. PETERS, J. M. Manager, White Lead Department, W. J. Mathewson and Company, Limited, 200 Water Street, New York, N. Y.

1907. PETTEE, EUGENE E. Civil Engineer, J. R. Worcester Company, 79 Milk Street, Boston, Mass.

1905. *PEW, J. HOWARD. Assistant Manager, Refinery, Sun Company, Marcus Hook, Pa.

1903. PHILLIPS, WILLIAM BATTLE. Birmingham Testing Laboratory, Birmingham, Ala.

1905. PHLEGAR, A. A., JR. Chemist, Norfolk and Western Railway, Roanoke, Va.

1907. PIERCE, DUNCAN H. Metallurgist, George N. Pierce Automobile Company, 1695 Elmwood Avenue, Buffalo, N. Y.

1906. PIERCE, JR., N. W. Purchasing Agent, Raritan Copper Works, Perth Amboy, N. J.

1903. *PINCHOT, GIFFORD. Forester, United States Department of Agriculture, Washington, D. C.

1904. *PITTSBURG FORGE AND IRON COMPANY. F. E. Richardson, Secretary, Pittsburg, Pa.

1905. *PITTSBURG TESTING LABORATORY, LIMITED. John M. Bailey, Secretary, 325 Water Street, Pittsburg, Pa.

1905. PLATT, J. G. Engineer of Tests, Erie Railroad Company, Meadville, Pa.

1902. *POLK, W. A. Sales Agent, The Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1906. *POLSON, JOSEPH A. Post Office Box No. 166, Agricultural College, Mich.

1904. *POMEROY, LEWIS R. Special Representative, Railway Department, General Electric Company, 44 Broad Street, New York, N. Y.

ELECTED.

1898. PORTER, JAMES MADISON. Professor of Civil Engineering, Lafayette College, Easton, Pa.

1907. POTTS, STEPHEN C. Assistant Chemist, Pennsylvania Railroad. *For Mail:* 2413 Broad Avenue, Altoona, Pa.

1903. POWELL, H. S. Sanitary Engineer, 327 Bond Building, Washington, D. C.

1904. POWELL, J. E. Chief Mechanical and Electrical Engineer, Office of Supervising Architect, Treasury Department, Washington, D. C.

1903. POWERS, W. A. Chief Chemist, Atchison, Topeka and Santa Fé Railroad, Topeka, Kan.

1904. *PRENTISS, GEORGE N. Chemist, Chicago, Milwaukee and St. Paul Railway, 226 Thirty-third Street, Milwaukee, Wis.

1904. PRESTON, S. R. Superintendent, Virginia Portland Cement Company, Fordwick, Augusta County, Va.

1906. PRICE, CHARLES E. Cement Inspector, North River Division, Pennsylvania Tunnel and Terminal Railroad Company, 564 West Thirty-third Street, New York, N. Y.

1903. PRICE, MORTON MOORE. Civil Engineer, Babcock and Wilcox Company, Bayonne, N. J.

1904. PRINCE, J. W. Vice-President, Freeborn Engineering and Construction Company, 708 Heist Building, Kansas City, Mo.

1906. PRITHAM, HENRY C. Metallurgical Chemist and Chemical Engineer, 142 Notre Dame Street, West, Montreal, Canada.

1905. *PROVOST, ANDREW J., JR. Engineer to Commissioner of Public Works, 518 Fifth Avenue, New York N. Y.

1907. PURDEN, HARRY B. Consulting Engineer, 538 South Eighth Street, Camden, N. J.

1904. PURDON, C. D Engineer, Maintenance of Way, Frisco System, Frisco Building, St. Louis, Mo.

1905. *QUICK, CHARLES DELAVAN. Assistant Superintendent, Chicago Portland Cement Company, Oglesby, Ill.

1904. QUIMBY, CHARLES H. Assistant Engineer, Yards and Buildings, American Bridge Company, 115 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

1903. QUIMBY, H. H. Assistant Engineer of Bridges, Bureau of Surveys, 863 North Twenty-third Street, Philadelphia, Pa.

ELECTED.

1907. Raguet, E. H. Chief Chemist, New York, New Haven and Hartford Railroad Company, West Haven, Conn.

1898. Railroad Gazette. W. H. Boardman, Editor, 83 Fulton Street, New York, N. Y.

1902. Railway and Engineering Review. W. M. Camp, Editor, 1305 Manhattan Building, Chicago, Ill.

1904. Ramage, J. C. Superintendent of Tests, Southern Railway Company, Alexandria, Va.

1904. *Ramsay, H. Martyn. General Inspector, Pennsylvania Railroad Company, Altoona, Pa.

1896. *Randolph, Lingan S. Professor of Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

1905. Read, C. P. Assistant Engineer, Interborough Rapid Transit Company, 75 East Fifty-Fourth Street, New York, N. Y.

1902. Reading Iron Company. Reading, Pa.

1905. Reber, Louis E. Dean, School of Engineering, The Pennsylvania State College, State College, Pa.

1904. Reeve, C. S. Assistant Inspector of Asphalt and Cement, District Building, Washington, D. C.

1902. Reid, David. General Foreman, Foundry Department, Canadian Westinghouse Company, Limited, 253 Wentworth Street, Hamilton, Canada.

1907. Reimer, Arthur A. Engineer and Superintendent, East Orange Water Department, City Hall, East Orange, N. J.

1906. Rew, W. E. Inspector of Asphalts and Cements, Post Office Box 451, Norfolk, Va.

1906. Reynders, J. V. W. Vice-President, Pennsylvania Steel Company, Steelton, Pa.

1905. Reynolds, J. C. Assistant Engineer Brooklyn Rapid Transit Railroad Commission, 6 West One Hundred and Twenty-ninth Street, New York, N. Y.

1898. Rice, Francis S. Engineer of Bridges, St. Louis and San Francisco Railroad Company, 943 Frisco Building, St. Louis, Mo.

1900. Richards, Joseph T. Chief Engineer, Maintenance of Way, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1902. *Richards, Joseph W. Professor of Metallurgy, Lehigh University, South Bethlehem, Pa.

ELECTED.

1902. RICHARDS, ROBERT H. Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

1904. *RICHARDS, W. D. Houghton and Richards, 150 Oliver Street, Boston, Mass.

1896. *RICHARDSON, CLIFFORD. Asphalt Expert, New York Testing Laboratory, Maurer, N. J.

1903. RICHARDSON, WILLARD D. Ceramic Engineer, Columbus, O.

1900. RICHTER, A. W. Professor of Experimental Engineering, University of Wisconsin, 929 University Avenue, Madison, Wis.

1906. *RIDDLE, WALTER. Vice-President, Sterling Varnish Company, Pittsburg, Pa.

1902. RIEGNER, W. B. Engineer of Bridges, Philadelphia and Reading Railway, Reading Terminal, Philadelphia.

1898. *RIEHLE, FREDERICK A. Riehlé Brothers Testing Machine Company, 1424 North Ninth Street, Philadelphia, Pa.

1906. RILEY, GEORGE N. National Tube Company, Frick Building, Pittsburg, Pa.

1907. *RINALD, C. D. Rinald Brothers, 1142 North Hancock Street, Philadelphia, Pa.

1907. RISTINE, JOHN D. Railway Representative, The Lowe Brothers Company, 470 The Rookery, Chicago, Ill.

1907. ROALD, JOHN. Civil Engineer, W. S. Barston and Company, 50 Pine Street, New York, N. Y.

1904. *ROBERTS, ALFRED E. Analytical and Consulting Chemist and Metallurgist, Bull and Roberts, 100 Maiden Lane, New York, N. Y.

1904. ROBERTSON, LESLIE S. Secretary of the Engineering Standards Committee, 28 Victoria Street, London, England.

1904. ROBINSON, A. F. Bridge Engineer, Atchison, Topeka and Santa Fé Railway System, 1000 Railway Exchange Building, Chicago, Ill.

1905. *ROBINSON, HOLTON D. Engineer in Charge of Manhattan Bridge, 21 Park Row, New York, N. Y.

1904. ROCK PRODUCTS. Fred K. Irvine, Technical Editor, 431 West Main Street, Louisville, Ky.

1906. ROCKWELL, GEORGE W. Chief Chemist, Lehigh Portland Cement Company, Mitchell, Ind.

ELECTED.

1906. RODGERS, S. M. Superintendent, North Works, American Steel and Wire Company, Worcester, Mass.

1900. *ROEBLING'S SONS COMPANY, JOHN A. H. J. Horne, Assistant Superintendent, Department of Wiredrawing, Trenton, N. J.

1904. ROEPPER, C. W. Metallurgical Engineer, Mount Airy Station, Philadelphia, Pa.

1905. *ROSENHEIM, A. F. Architect, H. W. Hellman Building, Los Angeles, Cal.

1905. *ROSSI, JAMES C. General Superintendent, National Fire Proofing Company, 71 Lewis Street, Perth Amboy, N. J.

1903. ROYAL, JOSEPH. Inspecting Engineer, P. O. Box 174, Rutledge, Pa.

1906. RUGGLES, WM. B. Mechanical Engineer, 39 Cortlandt Street, New York, N. Y.

1906. *RUSSELL, ERNEST JOHN. Architect, Chemical Building, St. Louis, Mo.

1904. RUTHENBURG, MARCUS. Electro-Metallurgical Engineer, Lockport, N. Y.

1898. SABIN, A. H. Chemist, 432 Sanford Avenue, Flushing, N. Y.

1902. SABIN, L. C. General Superintendent, St. Marys Falls Canal, Sault Ste. Marie, Mich.

1902. SAGUE, J. E. Vice-President, American Locomotive Company, 111 Broadway, New York, N. Y.

1904. SALMON, FREDERICK W. Civil and Mechanical Engineer, 127 South Central Avenue, Burlington, Iowa.

1904. SAUNDERS, GEORGE C. Gullitt-Manning Company, 80 Wall Street, New York, N. Y.

1902. SAUNDERS, WALTER M. Analytical and Consulting Chemist, 184 Whittier Avenue, Providence, R. I.

1896. *SAUVEUR, ALBERT. Metallurgical Engineer; Professor of Metallurgy, Harvard University; Rotch Building, Harvard University, Cambridge, Mass.

1903. SCARBOROUGH, F. W. Mining Engineer, 816 Mutual Building, Richmond, Va.

1904. SCHADE, G. C. 314 West College Street, Canonsburg, Pa.

1904. SCHENK, PIERCE D. Vice President and Assistant General Manager, The Dayton Malleable Iron Company, Dayton, O.

1904. *SCHMITT, F. E. Associate Editor, *The Engineering News*, 220 Broadway, New York, N. Y.

ELECTED

1905. SCHNEIDER, C. C. Consulting Engineer, Pennsylvania Building, Philadelphia, Pa.

1900. SCHNEIDER, HERMAN. Professor of Civil Engineering, University of Cincinnati, Cincinnati, O.

1906. SCHNELL, HARRY J. Manager, *The Painters Magazine*, 100 William Street, New York, N. Y.

1905. *SCHNIEWIND, F. Consulting Chemical Engineer; Vice-President, The United Coke and Gas Company, 17 Battery Place, New York, N. Y.

1906. SCHOOL OF ENGINEERING, University of Kansas. F. O. Martin, Dean, Lawrence, Kan.

1903. SCHROEDER, C. M. Chemist, 221 Pearl Street, New York, N. Y.

1902. SCHUERMAN, W. H. Dean of Engineering Department and Professor of Civil Engineering, Vanderbilt University, Nashville, Tenn.

1905. SCHWARTZ, ARCHIE W. Inspector, Bureau of Buildings, Borough of Manhattan, 65 West Eleventh Street, New York, N. Y.

1907. SCHWARTZ, HARRY A. Chemist, The National Malleable Castings Company, *For Mail:* 522 Tibbs Avenue, Indianapolis, Ind.

1907. SCOTT, DONALD G. James Stewart and Company, 14 South Newstead Avenue, St. Louis, Mo.

1904. *SCOTT, WILLIAM F. Structural Engineer, Aberdeen Chambers, Toronto, Can.

1902. *SCOTT, W. G. Chemist, J. I. Case Threshing Machine Company, 1109 Park Avenue, Racine, Wis.

1905. SCRIBNER, C. E. Chief Engineer, Western Electric Company, 463 West Street, New York, N. Y.

1898. SEAMAN, HARRY J. Superintendent, Atlas Cement Company, Catasauqua, Pa.

1902. SEAMAN, HENRY B. Civil Engineer, 40 Wall Street, New York, N. Y.

1906. SEARS, W. T. Engineering Bureau, Niles-Bement-Pond Company, Twenty-first and Callowhill Streets, Philadelphia, Pa.

1904. *SELLERS AND COMPANY, INCORPORATED, WILLIAM. Coleman Sellers, Jr., President, 1600 Hamilton Street, Philadelphia, Pa.

1906. *SEMET-SOLVAY COMPANY. O. S. Doolittle, Sales Agent, 17 Battery Place, New York, N. Y.

ELECTED.

1902. *SHANKLAND, E. C. AND R. M. Civil Engineers, 1106 Rookery, Chicago, Ill.

1907. *SHANNON, CHARLES. The Lowe Brothers and Company, 178 Fremont Street, Bellevue, Pa.

1907. SHATTON, S. W. Director, National Bureau of Standards Washington, D. C.

1907. SHAW, SAMUEL J., JR. Borough Engineer, Ridgefield Park, N. J.

1903. SHEAFF, J. C. Manager, Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1902. *SHELBY STEEL TUBE COMPANY. J. H. Nicholson, Third Vice-President, Frick Building, Pittsburg, Pa.

1904. SHERMAN, HERBERT. L. Sherman and Edwards, Chemical Engineers, 12 Pearl Street, Boston, Mass.

1906. SHERRERD, JOHN M. General Sales Agent, Taylor Iron and Steel Company, High Bridge, N. J.

1903. SHERRERD, MORRIS R. Engineer and Superintendent, Department of Water, City of Newark, 128 Halsey Street, Newark, N. J.

1902. SHERWIN-WILLIAMS COMPANY, THE. Paint and Varnish Makers, E. C. Holton, Chemist in Chief, 100 Canal Street, Cleveland, O.

1899. *SHIMER, PORTER W. Chemist and Metallurgist, Easton, Pa.

1906. SHULTS, CHARLES. Salesman, Worth Brothers Company, 111 Broadway, New York, N. Y.

1902. SHUMAN, JESSE J. Inspecting Engineer, Testing Department, Jones and Laughlin Steel Company, Pittsburg, Pa.

1904. SIMMONS, WILLIAM H. Superintendent, Badger Portland Cement Company, Appleton, O.

1904. SIMPSON BROTHERS CORPORATION. 166 Devonshire Street, Boston, Mass.

1906. SINCLAIR, D. G. Representative, Illinois Steel Company, 6304 Marchant Street, Pittsburg, Pa.

1903. *SKINNER, C. E. Electrical Engineer, Westinghouse Electric. and Manufacturing Company, East Pittsburg, Pa.

1904. *SKINNER, ORVILLE CAMPBELL. Superintendent, Open-Hearth Department, Standard Steel Works, P. O. Box 165, Burnham, Pa.

1906. SMART, L. A. Analyst for City Works Department, Old Waterworks, Winnipeg, Man.

ELECTED.

1907. SMITH, CHARLES E. Field Assistant, U. S. Geological Survey, Washington, D. C.

1906. SMITH, EMERY AND COMPANY. Chemists and Chemical Engineers, 651 Howard Street, San Francisco, Cal.

1906. *SMITH, E. B. In Charge Mechanical Laboratories, Drexel Institute, Thirty-second and Chestnut Streets, Philadelphia, Pa.

1902. *SMITH, H. E. Chemist, The Lake Shore and Michigan Southern Railway Company, Collinwood, O.

1905. SMITH, JAMES CRUICKSHANK. Chemical Engineer and Color Trade Expert, Holmdene, Colebrooke Avenue, West Ealing, W., England.

1904. SNODGRASS, A. E. Louisville Cement Company, Sellersburg, Ind.

1902. *SNOW, J. P. Bridge Engineer, Boston and Maine Railroad, Boston, Mass. *For Mail:* 58 Chandler Street, West Somerville, Mass.

1905. *SNOW, WALTER B. Manager, Advance Department, B. F. Sturtevant Company, Hyde Park, Mass. *For Mail:* 29 Russell Avenue, Watertown, Mass.

1904. *SOLVAY PROCESS COMPANY, THE. George B. Hartley, Chief Inspector, Syracuse, N. Y.

1904. SOMERVILLE, C. W. Computer in Charge of Tests, Building Department, Washington, D. C.

1903. *SOUTHER, HENRY. Consulting Metallurgical Engineer, State Chemist, 440 Capitol Avenue, Hartford, Conn.

1904. *SPACKMAN, HENRY S., ENGINEERING COMPANY. 42 North Sixteenth Street, Philadelphia, Pa.

1905. SPALDING, F. P. Professor of Civil Engineering, University of Missouri, Columbia, Mo.

1902. SPANGLER, H. W. Professor of Mechanical Engineering, University of Pennsylvania, Philadelphia, Pa.

1905. SPARE, C. R. Chemist, Wm. Cramp and Sons Ship and Engine Building Company, Beach and Ball Streets, Philadelphia, Pa.

1906. SPARHAWK, GEORGE F. Engineer, American Bridge Company, Ambridge, Pa.

1901. SPERRY, W. L. President and Manager, The Cumberland Hydraulic Cement and Manufacturing Company, Post Office Box 264, Cumberland, Md.

1906. SPRAGUE, L. G. Chemist, Virginia Portland Cement Company, Fordwick, Va.

ELECTED.

1907. STANDARD INSPECTION BUREAU, LIMITED. T. C. Irving, Jr., Secretary-Treasurer, 1314 Traders' Bank Building, Toronto, Can.

1902. *STANDARD STEEL WORKS. A. A. Stevenson, Assistant Superintendent, Burnham, Pa.

1905. *STANGER, R. H. HARRY. Consulting Engineer, Testing Works and Chemical Laboratories, 2 Broadway, Westminster, London, S. W., England.

1907. *STANSFIELD, ALFRED. Professor of Metallurgy, McGill University, Montreal, Canada.

1903. STAPLETON, F. M. Inspector, Chicago and Northwestern Railway, 504 Smithfield Street, Pittsburg, Pa.

1907. STATE GEOLOGICAL SURVEY. H. F. Bain, Director, Urbana Ill.

1904. *STATTELMANN, G. R. 37 West Washington Street, Dayton, Ohio.

1906. STEFFENS, WM. FREDERICK. Engineer of Bridges and Buildings, South and Western Railroad, Johnson City, Tenn.

1899. STEINMAN, A. J. Chairman, Pennsylvania Iron Company, Limited, Lancaster, Pa.

1906. STEPHENSON, J. T. Inspector, Southern Railway Company, Post Office Box 66, Phœnixville, Pa,

1896. *STEVENSON, A. A. Superintendent, Standard Steel Works, Burnham, Mifflin County, Pa.

1903. STEWART, CLINTON R. Assistant Superintendent, Open Hearth Department, Cambria Steel Company, Johnstown, Pa.

1904. STEWART, P. M. Consulting Engineer, The Nevada, Broadway and Seventieth Street, New York, N. Y.

1906. STILLMAN, HOWARD. Mechanical Engineer and Engineer of Tests, Southern Pacific Company, 2430 Piedmont Avenue, Berkeley, Cal.

1899. *STILLMAN, THOMAS B. Professor of Chemistry, Stevens Institute of Technology, Hoboken, N. J.

1907. STOEK, H. H. Editor, *Mines and Minerals*, Scranton, Pa.

1907. STOKES, HENRY N. Associate Chemist, United States Bureau of Standards, Washington, D. C.

1903. STOREY, W. B., JR. Chief Engineer, Atchison, Topeka and Sante Fé Railroad Company, 1033 Railway Exchange Building, Chicago, Ill.

ELECTED.

1904. Stormer, Edward J. Chemist, The Patton Paint Company, Milwaukee, Wis.

1906. Storrs, L. S. Engineer of Tests, New York, New Haven and Hartford Railroad Company, Hew Naven, Conn.

1902. *Stoughton, Bradley. Adjunct Professor of Metallurgy and Consulting Metallurgist, Columbia University, New York, N. Y.

1906. Stout, Howard A. Architect, Post Office Box 617, Atlantic City, N. J.

1907. Strange, William Wallace, Jr. Assistant Engineer of Tests, Anaconda Copper Mining Company, Locker Box 298, Anaconda, Mont.

1903. Stratton, E. Platt. 66–70 Beaver Street, New York, N. Y.

1907. Stratton, S. W. Director, United States Bureau of Standards, Washington, D. C.

1903. Streeter, Lafayette P. Air Brake Inspector, Southern Pacific Company. *For Mail:* Post Office Box 1345, Los Angeles, Cal.

1896. *Strobel, Charles L. Consulting Engineer, 1744 Monadnock Block, Chicago, Ill.

1904. *Stuetz, E. Vice-President and Treasurer, The Goldschmidt Thermit Company, 90 West Broad Street, New York, N. Y.

1906. Suydam, Richard S. President, M. B. Suydam Paint Company, Pittsburg, Pa.

1896. *Swain, George F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.

1903. *Swanberg, F. L. Secretary, The D. T. Williams Valve Company, 904–910 Broadway, Cincinnati, O.

1907. *Swenson, P. M. Superintendent of Bridges and Buildings, Minneapolis, St. Paul and Sault Sainte Marie Railway Company, Shoreham Shops, Minneapolis, Minn.

1903. *Swensson, Emil. Consulting Engineer, Frick Building, Pittsburg, Pa.

1905. *Taber, George H. General Manager, Gulf Refining Company, Frick Building, Pittsburg, Pa.

1903. Taggart Howard. Engineer of Tests, Lukens Iron and Steel Company, Post Office Box 632, Coatesville, Pa.

1898. *Talbot, Arthur N. Professor of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill.

ELECTED

1902. *TALBOT, HENRY P. Professor of Inorganic and Analytical Chemistry, Massachusetts Institute of Technology, Boston, Mass.

1904. TASSIN, WIRT. Chemist; Assistant Curator, National Museum, Washington, D. C.

1904. TAUBENHEIM, ULRICH E. Manager, City Water Works, Archangel, Russia.

1906. TAYLOR, KNOX. General Manager, Taylor Iron and Steel Company, High Bridge, N. J.

1900. TAYLOR, WILLIAM PURVES. Engineer in Charge, Testing Laboratory, 318 City Hall, Philadelphia, Pa.

1896. *TECHNISCHER VEREIN, NEW YORK. Carl Kaelble, Secretary, Room 719, Engineering Building, 29 West Thirty-ninth Street, New York, N. Y.

1896. *TECHNISCHER VEREIN, PITTSBURG. Gustav A. Stielrin, Secretary, 166 Robinson Street, Pittsburg, Pa.

1896. TECHNISCHER VEREIN, WASHINGTON. Paul Bausch, Corresponding Secretary, 3418 Brown Street, N. W., Washington, D. C.

1907. THATCHER, C. R. The Eastern Steel Company, Pottsville, Pa.

1902. THACHER, EDWIN. Consulting Engineer; Member, Concrete-Steel Engineering Company, Park Row Building, New York, N. Y.

1907. THELEN, ROLF. Engineer of Timber Tests, Forest Service, Washington, D. C.

1906. *THOMAS, A. R. Commonwealth Steel Company, St. Louis, Mo.

1900. *THOMAS, DAVID. Logan Iron and Steel Company, Burnham, Pa.

1906. THOMPSON, G. SAXTON. Assistant in Mechanics, Rensselaer Polytechnic Institute, 861 Second Avenue, Upper Troy, Troy, N. Y.

1903. *THOMPSON, GUSTAVE W. Chemist, National Lead Company, 129 York Street, Brooklyn, N. Y.

1905. *THOMPSON, HUGH L. Consulting Engineer, Waterbury, Conn.

1907. *THOMPSON, JOHN FAIRFIELD. The Oxford Copper Company, Chief of Testing Department, New Brighton, Staten Island, N. Y.

1904. *THOMPSON, SANFORD E. Civil Engineer, Newton Highlands, Mass.

ELECTED.

1904. THOMSON, FRANK K. Barrett and Thomson, Post Office Box No. 574, Raleigh, N. C.

1906. TIEMANN, HARRY D. Assistant Forest Inspector, U. S. Forest Service, Yale Forest School, New Haven, Conn.

1905. *TILDEN, C. J. Assistant Professor of Civil Engineering, University of Michigan, 320 Engineering Building, Ann Arbor, Mich.

1903. *TOCH, MAXIMILIAN. Paint Manufacturer, 320 Fifth Avenue, New York, N. Y.

1903. TOMKINS, CALVIN. Manufacturer, 17 Battery Place, New York, N. Y.

1903. TOUCEDA, ENRIQUE. Chemist and Metallurgist, 51 State Street, Albany, N. Y.

1906. TRAUTWEIN, A. P. President, Carbondale Machine Company, Carbondale, Pa.

1907. *TRAUTWINE, JOHN C., JR. Civil Engineer, 257 South Fourth Street, Philadelphia, Pa.

1906. TRETCH, WM. J. Superintendent, Riehlé Brothers Testing Machine Company, 1424 North Ninth Street, Philadelphia, Pa.

1905. *TRIST, N. B. Assistant to Vice-President, The Schoen Steel Wheel Company, Box 1212, Pittsburg, Pa.

1904. TROOIEN, O. N. Assistant in Mechanical Engineering, South Dakota Agricultural College, Brookings, S. Dak.

1906. *TURNER, HENRY C. President, Turner Construction Company, 11 Broadway, New York, N. Y.

1902. *TURNEAURE, F. E. Dean of the College of Mechanics and Engineering, University of Wisconsin, Madison, Wis.

1906. *TURNEY, OMAR A. City Engineer, Phoenix, Ari.

1902. UMSTEAD, C. H. Consulting Engineer, Merchantville, N. J.

1907. UNION STEEL CASTING COMPANY. C. C. Smith, President, Sixty-first and Butler Streets, Pittsburg, Pa.

1907. UNITED STATES GUTTA PERCHA PAINT COMPANY. Herbert W. Rice, Secretary, Providence, R. I.

1906. VANDEVORT, F. F. Eastern Sales Agent, Wheeling Mold and Foundry Company, 374 Fifth Avenue, New York, N. Y.

1904. VAN CLEVE, A. H. Resident Engineer, The Niagara Falls Power Company, Niagara Falls, N. Y.

ELECTED.

1903. VAN GUNDY, C. P. Chief Chemist, Baltimore and Ohio Railroad, Mont Clare, Baltimore, Md.

1902. *VAN ORNUM, J. L. Professor of Civil Engineering, Washington University, St. Louis, Mo.

1903. VANNIER, CHARLES H. Consulting Engineer, 76 Harvard Place, Buffalo, N. Y.

1896. VOGT, A. S. Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1907. VOIGHT, M. L. Superintendent of Bordens Shops, 932 Seventy-third Street, Brooklyn, N. Y.

1904. *VON AMMON, S. Consulting Engineer, Oswaldestre House, Norfolk Street, Strand, London, W. C., England.

1906. VON MARLE, C. M. Chemist, Pratt and Lambert, 79 Tonawanda Street, Buffalo, N. Y.

1903. VON SCHRENK, HERMANN. Von Schrenk, Fulks and Kammerer, Consulting Timber Engineers, Tower Grove and Fled Avenue, St. Louis, Mo.

1902. VOORHEES, S. S. Engineer of Tests, Treasury Department, Washington, D. C.

1903. *VREDENBURGH, WATSON, JR. Member, Hildreth and Company, Engineers, 50 Broadway, New York, N. Y.

1904. *WACHTER, CHARLES LUCAS. Assistant Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

1896. WADDELL, J. A. L. Consulting Civil Engineer, Kansas City, Mo.

1907. WADSWORTH, J. E. Resident Engineer, American Bridge Company, 42 Broadway, New York, N. Y.

1904. WAGENHORST, JAMES H. Westinghouse Machine Company, Pittsburg, Pa.

1899. *WAGNER, SAMUEL TOBIAS. Assistant Engineer, Philadelphia and Reading Railway, Huntingdon Street Station, Philadelphia, Pa.

1903. WAID, D. EVERETT. Architect, 156 Fifth Avenue, New York, N. Y.

1904. WALDO BROS. 102 Milk Street, Boston, Mass.

1902. *WALKER, JOSEPH F. Chemist, The Protectus Company, Bridgeport, Pa.

1907. WALKER, PERCY H. Chief Chemist, Contracts Laboratory, Bureau of Chemistry, Washington, D. C.

ELECTED.

1903. WALKER, R. F. Cement Tester in Charge, Rapid Transit Railway, New York, 412 Turner Street, Allentown, Pa.

1905. *WALKER, WILLIAM H. Professor of Industrial Chemistry, Massachusetts Institute of Technology, 24 Trinity Place, Boston, Mass.

1904. *WALLACE, E. C. Post Office Box 241, East Auburn, Cal.

1903. *WALSH, W. F. American Brake Shoe and Foundry Company, 408 Allen Avenue, Richmond, Va.

1903. *WALTER, LEE W. Cement Inspector, Erie Railroad, Ninth and Provost Streets, Jersey City, N. J.

1905. WARD, C. E. Oil Inspector, Pittsburg Coal Company, Banksville, Pa.

1904. WARDELL, H. R. General Sales Agent, Barber Asphalt Paving Company, Philadelphia, Pa.

1905. *WARMAN, F. C. United States Assistant Engineer, 1000 Twenty-second Street, Washington, D. C.

1903. WARNER, GEORGE C. Sullivan Machinery Company, Post Office Box 33, Claremont, N. H.

1905. WARREN BROTHERS COMPANY, 93 Federal Street, Boston, Mass.

1907. WASHBURN, FRANK E. Assistant Engineer, St. Louis Electric Bridge Company, Salisbury and Hall Streets, St. Louis, Mo.

1906. WASHINGTON UNIVERSITY. C. M. Woodward, Dean of School of Engineering and Architecture, St. Louis, Mo.

1904. WASON, LEONARD C. President, Aberthaw Construction Company, 8 Beacon Street, Boston, Mass.

1906. WEEKS, PAUL. Norton Megaw and Company, Limited, Rio de Janeiro, Brazil.

1904. WEBB, Z. Chief Chemist, Eliza Furnace, Jones and Laughlin Steel Company, *For Mail:* 861 Lilac Street, Pittsburg, Pa.

1900. *WEBSTER, GEORGE S. Chief Engineer and Surveyor, Bureau of Surveys, 318 City Hall, Philadelphia, Pa.

1898. *WEBSTER, WILLIAM R. Civil Engineer, 411 Walnut Street, Philadelphia, Pa.

1906. WELD, HAROLD KENNETH. Assistant to Material Engineer, Engineering Department, Chicago Telephone Company, 127 College Street, Elgin, Ill.

ELECTED.

1903. *WEMLINGER, J. R. President, Wemlinger Steel Piling Company, 11 Broadway, New York, N. Y.

1904. WENTWORTH, CHARLES C. Principal Assistant Engineer, Norfolk and Western Railway, Roanoke, Va.

1905. WENTZ, DANIEL B. President, Stonega Coal and Coke Company, 1723 Land Title Building, Philadelphia, Pa.

1897. WEST, THOMAS D. Foundry Expert, Sharpsville, Pa.

1904. WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, L. A. Osborne, Vice-President, Post Office Box 911, Pittsburg, Pa.

1907. WESTON, FREDERICK W. Foreman, Spring Department, Standard Steel Works, Burnham, Pa.

1906. WETTACH, CHARLES D. Secretary, W. W. Lawrence and Company, West Carson Street, Pittsburg, Pa.

1906. WHARFF, WM. H. Architect, 2000 Delaware Street, Berkeley, Cal.

1906. WHEELER, EDWARD J. Consulting Chemist, 79 Chapel Street, Albany, N. Y.

1905. WHEELER, FRANK A. Inspecting Engineer, Harrison Building, Philadelphia, Pa.

1905. WHINERY, S. Consulting Engineer on Pavements, Borough of Manhattan, New York, 95 Liberty Street, New York, N. Y.

1906. WHITE, EVERETT HANSON. In charge Engineering Department, E. C. and B. Company Plant, No. 1, 91 Fremont Street, Bridgeport, Conn.

1906. WHITE, G. D. Manager, Patton Paint Company, Newark, N. J.

1900. *WHITEHEAD, J. W., JR. Preservative Coatings, 1 Madison Avenue, New York, N. Y.

1902. WHITNEY, WILLIS R. Research Laboratory, General Electric Company, Schenectady, N. Y.

1898. WICKHORST, MAX H. Engineer of Tests, Chicago, Burlington and Quincy Railway Company, Aurora, Ill.

1904. WILCOX, LEWIS G. Inspector of Steel, New York Rapid Transit Railroad Commission, 613 Empire Building, Pittsburg, Pa.

1906. WIELAND, CHARLES F. Consulting Engineer, 911 Mutual Saving Bank Building, San Francisco, Cal.

1902. WILHELM COMPANY, THE A. Paint Makers, Reading, Pa.

ELECTED.

1898. WILLE, H. V. Assistant to Superintendent, Baldwin Locomotive Works, 500 North Broad Street, Philadelphia, Pa.

1905. WILLIAMSON, SYDNEY B. Consulting Engineer, Culebra, Canal Zone, Panama.

1906. WILSON, EDWARD F. Chemist, Westmoreland Coal Company, Irwin, Pa.

1906. WINCHESTER REPEATING ARMS COMPANY. R. L. Penny, in Charge of Physical Laboratory, New Haven, Conn.

1900. *WING, CHARLES B. Professor of Structural Engineering, Stanford University, Cal.

1907. WITHEY, MORTON OWEN. Instructor in Mechanics, University of Wisconsin. *For Mail:* 430 Francis Street, Madison, Wis.

1903. WITTMAN, N. B. Potts and Wittman, North American Building, Philadelphia, Pa.

1906. WOLF, OTTO C. Engineer and Architect, 1025 Arch Street, Philadelphia, Pa.

1903. *WOLFEL, PAUL L. Chief Engineer, American Bridge Company, 362 Green Lane, Roxborough, Philadelphia, Pa.

1902. *WOOD AND COMPANY, R. D., Founders. Walter Wood, 400 Chestnut Street. Philadelphia, Pa.

1903. WOOD, EDWARD R., JR. Manufacturer, 400 Chestnut Street, Philadelphia, Pa.

1903. WOOD, F. W. President, Maryland Steel Company, Sparrows Point, Md.

1900. *WOOD, WALTER. Cast-Iron Pipe Manufacturer, R. D. Wood and Company, 400 Chestnut Street, Philadelphia, Pa.

1906. WOODCOCK, W. H. Consulting Engineer, 506 White Building, Buffalo, N. Y.

1903. WOODMAN, DURAND. Analytical and Technical Chemist, 80 Beaver Street, New York, N. Y.

1906. WOODS, R. W. Chief Chemist, Northern Pacific Railway Company, General Office Building, St. Paul, Minn.

1906. WOODWELL, JULIAN E. Inspector of Electric Light Plants, Treasury Department, Washington, D. C.

1900. *WOOLSON, IRA H. Adjunct Professor of Mechanical Engineering, Columbia University, New York, N. Y.

1904. *WORCESTER, JOSEPH R. J. R. Worcester and Company, 79 Milk Street, Boston, Mass.

ELECTED.

1905. WORCESTER POLYTECHNIC INSTITUTE. William W. Bird, Director of the Department of Mechanical Engineering, Worcester, Mass.

1904. WORMELEY, P. L., JR. Engineer of Tests, Division of Tests, United States Department of Agriculture, Washington, D. C.

1903. WORTHINGTON, CHARLES. Consulting Engineer, 204 West Ninety-fourth Street, New York, N. Y.

1906. *WYMAN AND GORDON COMPANY, THE. George F. Fuller, General Superintendent and Secretary, Worcester, Mass.

1907. YOUNG, J. BERTRAM. Chemist, Philadelphia and Reading Railway Company, Reading, Pa.

1905. YOUNG, JOHN P. General Manager, Youngstown Car Manufacturing Company, Youngstown, O.

1903. ZEHNDER, C. H. President, Alleghany Ore and Iron Company, Pennsylvania Building, Philadelphia, Pa.

GEOGRAPHICAL DISTRIBUTION OF MEMBERS.

Alabama	7	Massachusetts	57	Texas	1
Arizona	2	Michigan	9	Utah	1
California	19	Minnesota	5	Virginia	24
Colorado	6	Missouri	30	Washington	2
Connecticut	15	Montana	2	West Virginia	3
Delaware	6	Nebraska	4	Wisconsin	14
Dist. of Columbia	39	New Hampshire	1	Brazil	1
Georgia	1	New Jersey	43	Canada	23
Idaho	1	New York	218	Cuba	1
Illinois	63	North Carolina	2	England	7
Indiana	12	Ohio	42	France	1
Iowa	4	Oregon	8	Germany	3
Kansas	5	Pennsylvania	255	Panama	2
Kentucky	4	Rhode Island	5	Philippine Is.	1
Louisiana	1	South Carolina	1	Porto Rico	1
Maine	1	South Dakota	1	Russia	1
Maryland	11	Tennessee	3	South Africa	1

Total membership 970

Total number holding membership also in the International Association for Testing Materials 265

DECEASED MEMBERS.

Name.	Date of Membership.	Date of Death.
J. W. Anderson	1896	May 18, 1905.
Edward Atkinson	1903	December 11, 1905
W. P. Black	1896	December 12, 1902
Henry I. Budd	1903	January 14, 1905
Thomas M. Drown	1899	November 16, 1904
Henry U. Frankel	1903	December 8, 1903.
Charles Jarecki	1896	January 26, 1901.
J. B. Johnson	1899	June 23, 1902.
W. C. Johnson	1900	December 15, 1906.
G. M. McCauley	1898	May 25, 1901.
George S. Morison	1896	July 1, 1903.
Henry Morton	1896	May 9, 1902.
Geo. Tatnall,	1906	September 13, 1906.
Robert H. Thurston	1896	October 25, 1903.
H. H. Wright	1904	June 22, 1905.
W. H. Wyman	1905	November 11, 1905.

PAST OFFICERS.

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated the American Section of the International Association for Testing Materials.

The officers and members of the Executive Committee during this four-year period were as follows:

CHAIRMEN:

MANSFIELD MERRIMAN, 1898–1900.

HENRY M. HOWE, 1900–1902

VICE-CHAIRMEN:

HENRY M. HOWE 1898-1900.

CHARLES B. DUDLEY 1900–1902.

SECRETARIES:

RICHARD L. HUMPHREY, 1898–1900.

J. M. PORTER, 1900–1902

TREASURERS:

PAUL KREUZPOINTNER, 1898–1900.

R. W. LESLEY, 1900–1902

MEMBERS OF EXECUTIVE COMMITTEE:

GUS. C. HENNING, 1898–1900.

ALBERT LADD COLBY, 1900-1902.

STANDING ADVISORY COMMITTEES.

ON IRON AND STEEL.

WILLIAM R. WEBSTER, *Chairman.*

C. Kirchhoff, H. V. Wille.

ON CAST IRON.

RICHARD MOLDENKE, *Chairman.*

Henry Souther, Thos. D. West.

ON CEMENT AND CONCRETE.

CLIFFORD RICHARDSON, *Chairman.*

Richard L. Humphrey, Spencer B. Newberry.

ON BRICK AND TERRA-COTTA PRODUCTS.

EDWARD ORTON, JR., *Chairman.*

H. O. Hofman, W. D. Richardson

ON PRESERVATIVE COATINGS.

G. W. THOMPSON, *Chairman.*

Robert Job, S. S. Voorhees.

ON TESTS AND TESTING APPARATUS.

GAETANO LANZA, *Chairman.*

Mansfield Merriman, Tinius Olsen.

TECHNICAL COMMITTEES
OF THE
AMERICAN SOCIETY FOR TESTING MATERIALS.

Committee A, on Standard Specifications for Iron and Steel.

William R. Webster, *Chairman.*
Edgar Marburg, *Secretary.*

- American Steel and Wire Company,
  - F. H. Daniels.
- Bethlehem Steel Company,
  - E. O'C. Acker.
- Cambria Steel Company,
  - George E. Thackray.
- Carnegie Steel Company,
  - W. A. Bostwick.
- Robert A. Carter.
- Central Iron and Steel Company,
  - James B. Bailey.
- James Christie.
- Charles S. Churchill.
- F. H. Clark.
- Albert Ladd Colby.
- J. Allen Colby.
- Colorado Fuel and Iron Company,
  - J. B. McKennan.
- John Sterling Deans.
- P. H. Dudley.
- Franklin Institute,
  - Alex. E. Outerbridge, Jr.
- J. E. Greiner.
- Robert W. Hunt Company.
- Illinois Steel Company,
  - P. E. Carhart.
- Jones and Laughlin Steel Company,
  - Willis L. King.
- E. F. Kenney.
- Gaetano Lanza.
- Lackawanna Steel Company,
  - F. E. Abbott.
- Lukens Iron and Steel Company,
  - Charles L. Huston.
- S. S. Martin.
- John McLeod.
- Richard Moldenke
- National Tube Company,
  - Frank N. Speller.
- L. R. Pomeroy.
- The Osborn Engineering Company,
  - Frank C. Osborn.
- The Pennsylvania Steel Company,
  - J. V. W. Reynders.
- Reading Iron Company.
- Joseph T. Richards.
- John A. Roebling's Sons Company,
  - H. J. Horne.
- C. C. Schneider.
- Shelby Steel Tube Company,
  - J. H. Nicholson.
- J. P. Snow.
- Standard Steel Works,
  - A. A. Stevenson.
- J. A. L. Waddell.
- Samuel T. Wagner.
- Max H. Wickhorst.
- H. V. Wille.
- R. D. Wood and Company,
  - Walter Wood.

Committee B, on Standard Specifications for Cast Iron and Finished Castings.

Walter Wood, *Chairman.*
Richard Moldenke, *Secretary.*

- Hugh W. Adams.
- James A. Beckett.
- Joseph W. Bramwell.
- Colorado Fuel and Iron Company,
  - J. B. McKennan.
- Albert Ladd Colby.

Committee B.—*Continued.*

Edgar S. Cook.
H. A. Croxton.
George M. Davidson.
H. E. Diller.
W. C. Du Comb.
Charles B. Dudley.
B. F. Fackenthal, Jr.
L. M. Fenner.
A. I. Findley.
Stanley G. Flagg, Jr.
W. K. Hatt.
J. A. Hays.
W. W. Hearne.
J. O. Henshaw.
P. S. Hildreth.
Henry M. Howe.
Illinois Steel Company,
  P. E. Carhart.
International Harvester Company,
  John G. Wood.
Robert Job.
Jones and Laughlin Steel Company,
  Willis L. King.
J. A. Kinkead.
Paul Kreuzpointner.
Gaetano Lanza.
William W. Lobdell.
A. M. Loudon.
Charles F. McKenna.
R. S. MacPherran.
Mansfield Merriman.
Tinius Olsen
Alex. E. Outerbridge, Jr.
Leonard Peckitt.
L. S. Randolph.
David Reid.
Walter M. Saunders.
Albert Sauveur.
W. G. Scott.
Henry Souther.
H. W. Spangler.
Technischer Verein, Pittsburg,
  Paul Bausch.
Enrique Touceda.
C. H. Vannier.
W. R. Webster.
Thomas D. West.
H. V. Wille.
N. B. Wittman.
E. R. Wood, Jr.
F. W. Wood.
I. H. Woolson.
O. H. Zehnder.

Committee C, on Standard Specifications for Cement.

George F. Swain, *Chairman.*
George S. Webster, *Vice-Chairman.*
Richard L. Humphrey, *Secretary.*

Booth, Garrett & Blair.
Edward T. Cairns.
Spencer Cosby
A. W. Dow.
L. Henry Dumary.
W. S. Eames.
A. F. Gerstell.
Edward M. Hagar.
W. H. Harding.
Olaf Hoff.
W. J. Kelley.
Robert W. Lesley.
F. H. Lewis.
John B. Lober.
Andreas Lundteigen
Charles F. McKenna.
W. W. Maclay.
Charles A. Matcham.
A. W. Munsell.
Spencer B. Newberry.
James Madison Porter.
Joseph T. Richards.
Clifford Richardson.
L. C. Sabin.
Harry J. Seaman.
Henry S. Spackman Engineering
  Company.
S. S. Voorhees.

COMMITTEE D, ON STANDARD SPECIFICATIONS FOR PAVING AND BUILDING BRICK.

LOGAN WALLER PAGE, *Chairman.*

Ira O. Baker.
Edward Orton, Jr.
W. D. Richardson.
Arthur N. Talbot.
Ira H. Woolson.

COMMITTEE E, ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

S. S. VOORHEES, *Chairman.*
JOSEPH F. WALKER, *Secretary.*

W. A. Aiken.
James Christie.
The Joseph Dixon Crucible Company,
  Malcolm MacNaughton.
Charles B. Dudley.
A. W. Dow.
C. N. Forrest.
Geo. B. Heckel.
International Acheson Graphite Company,
  C. L. Collins.
Robert Job.
P. C. McIlliney.
W. A. Polk.
A. H. Sabin.
Wirt Tassin.
G. W. Thompson.
Wm. R. Webster.
J. W. Whitehead, Jr.
Max H. Wickhorst.
The A. Wilhelm Company,
  Charles J. Davies.

COMMITTEE F, ON HEAT TREATMENT OF IRON AND STEEL.

HENRY M. HOWE, *Chairman.*

William Campbell.
Albert Sauveur.
Bradley Stoughton.

COMMITTEE G, ON THE MAGNETIC TESTING OF IRON AND STEEL.

J. WALTER ESTERLINE, *Chairman.*

W. J. Beck.
John A. Capp.
H. E. Diller.
Richard Moldenke.
J. A. Mathews.
C. E. Skinner.

COMMITTEE H, ON STANDARD TESTS FOR ROAD MATERIALS.

LOGAN WALLER PAGE, *Chairman.*
ARTHUR N. JOHNSON, *Secretary.*

Ira O. Baker.
W. H. Broadhurst.
A. Cushman.
A. W. Dow.
W. S. Godwin.
W. K. Hatt.
G. P. Hemstreet.
J. A. Holmes.
Jos. W. Hunter.
C. A. Kenyon.
Frederic A. Kummer.
A. Marsten.
J. J. Morrow.
Clifford Richardson.
Calvin Tomkins.
E. C. Wallace.

Committee I, on Reinforced Concrete.

F. E. Turneaure, *Chairman.*
R. W. Lesley, *Vice-Chairman.*
Richard L. Humphrey, *Secretary.*

W. B. Fuller.
E. Lee Heidenreich.
A. L. Johnson.
Gaetano Lanza.
Edgar Marburg.
C. M. Mills.
L. S. Moisseff.
H. H. Quimby.
W. P. Taylor.
S. E. Thompson.
S. T. Wagner.
G. S. Webster.

Committee J, on Standard Specifications for Coke.

C. H. Zehnder, *Chairman.*
Richard Moldenke, *Secretary.*

Anaconda Copper Mining Company, E. P. Mathewson.
Warren Blauvelt.
W. H. Blauvelt.
Wm. A. Bole.
Edgar S. Cook.
John Donahoe.
Chas. B. Dudley.
D. T. Evans.
B. F. Fackenthal, Jr.
Geo. H Finn.
H. L. Haldeman.
J. A. Holmes.
J. A. Kinkead.
John Lloyd.
Thomas Lynch.
T. D. Lynch.
E. C. Means.
F. Schniewind.
W. G. Scott.
W. B. Snow.
Henry Souther.
D. B. Wentz.
H. V. Wille.
Walter Wood.

Committee K, on Standard Methods of Testing.

Gaetano Lanza, *Chairman.*

Geo. A. Bostwick.
Wm. Campbell.
James Christie.
John S. Deans.
Chas. B. Dudley.
W. K. Hatt.
J. E. Howard.
Henry M. Howe.
A. P. Hume.
Richard L. Humphrey.
Mansfield Merriman.
Richard Moldenke.
E. D. Nelson.
H. P. Talbot.
Geo. E. Thackray.
H. V. Wille.
Ira H. Woolson.

Committee L, on Standard Specifications and Tests for Clay and Cement Sewer Pipes.

Rudolph Hering, *Chairman.*
A. J. Provost, Jr., *Vice-Chairman.*

W. C. Foster.
F. C. Hitchcock.
W. A Hull.
G. Kauffman.
J. C. Rossi.

Committee M, on Standard Specifications for Staybolt Iron.

H. V. Wille, *Chairman.*

F. B. Allen.
American Iron and Steel Manufacturing Company.
Brown and Company.
F. H. Clark.
J. A. Kinkead.
E. D. Nelson.
J. C. Ramage.

Commitee N, on Standard Tests for Lubricants.

A. H. Gill, *Chairman.*
J. M. Jeffers, *Secretary.*

Bureau of Standards,
 S. W. Stratton.
W. A. Converse.
W. M. Davis.
A. W. Dow.
J. L. Gray.
A. P. Hume.
E. D. Nelson.
J. H. Pew.
Geo. H. Taber.
C. E. Ward.

Committee O, on Uniform Speed in Commercial Testing.

Paul Kreuzpointner, *Chairman.*
H. V. Wille, *Secretary.*

W. A. Bostwick.
F. O. Bunnell.
H. H. Campbell.
A. P. Hume.
J. A. Kinkead.
S. M. Marshall.
Tinius Olsen.
A. A. Stevenson.

Committee P, on Fire-proofing Materials.

Ira H. Woolson, *Chairman.*
R. P. Miller, *Secretary.*

W. W. Ewing.
John R. Freeman.
H. W. Hodge.
C. W. Somerville.
Edwin Thacher.
D. E. Waid.

Committee Q, on Standard Specifications for the Grading of Structural Timber.

Hermann von Schrenk, *Chairman.*
W. K. Hatt, *Secretary.*

C. R. Bangs
Chas. H. Davis.
A. O. Elzner.
Geo. H. Emerson.
B. E. Fernow.
R. S. Kellogg.
H. W. Lohmann.
R. A. Long.
A. J. Maclean
A. N. Mansfield.
A. F. Rosenheim.

COMMITTEE R, ON UNIFORM SPECIFICATIONS FOR BOILERS.

E. D. MEIER, *Chairman.*

F. B. Allen.
R. C. Carpenter.
H. J. Hartley.
Chas. L. Huston.
John McLeod.
J. E. Sague.
H. V. Wille.

COMMITTEE S, ON WATERPROOFING MATERIALS.

W. A. AIKEN, *Chairman.*
A. W. DOW, *Secretary.*

Barrett Manufacturing Company,
  W. S. Babcock.
S. R. Church.
E. W. DeKnight.
T. H. Ellis.
A. W. Munsell.
C. S. Reeve.
W. P. Taylor.
Maximilian Toch.
U. S. War Department,
  Capt. Chester A. Harding.
Warren Brothers Company,
  A. E. Schutte.

COMMITTEE T, ON THE TEMPERING AND TESTING OF STEEL SPRINGS AND STANDARD SPECIFICATIONS FOR SPRING STEEL.

J. A. KINKEAD, *Chairman.*

W. A. Bostwick.
F. O. Bunnell.
F. D. Carney.
J. C. Davis.
Nathan H. Davis.
Alan Lukens.
Archibald M. McCrea.
R. W. Mahon.
E. D. Nelson.
A. A. Stevenson.
Max. H. Wickhorst.
H. V. Wille.

COMMITTEE U, ON THE CORROSION OF IRON AND STEEL.

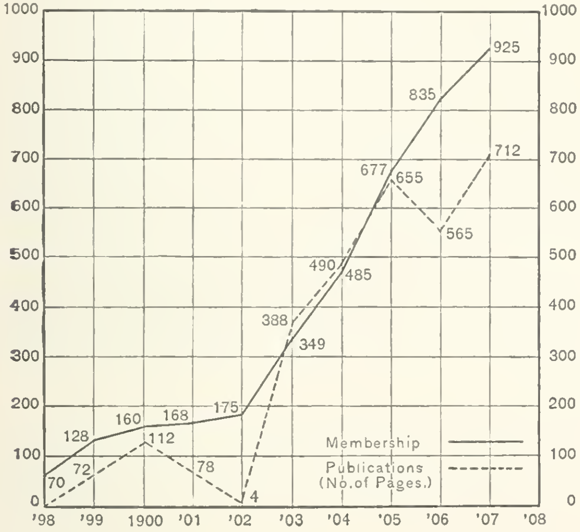
ALLERTON S. CUSHMAN, *Chairman.*
WM. H. WALKER, *Secretary.*

William Campbell.
Robert A. Carter.
H. M. Howe.
Charles L. Huston.
Robert Job.
William M. Parks.
F. N. Speller.
Max H. Wickhorst.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Since the Ninth Annual Meeting of the Society the Executive Committee has held four regular meetings of which one was informal, owing to the absence of a quorum. An abstract of the Minutes of these meetings is appended to this report.

The activity of the Society during the past year as reflected in the work of its committees and in its publications has been highly satisfactory. Volume VI of the Proceedings, containing 712 pages of printed matter and 290 illustrations, exceeds all previous volumes, both in scope and variety of contents. Many of the standing technical committees have held meetings during the year and will present reports at this meeting.



The growth of membership from 835 to 925 has not fully met expectations, and the Executive Committee desires again to take occasion to urge the members to bring the advantages of the Society to the notice of persons interested in the broad field it aims to cover and qualified to assist in the furtherance of the same. The losses from resignations and members dropped on account of arrears in dues have also been substantially larger this year than in previous years, so that although 156 new members have been admitted, the net gain is only 90.

The large cost of Volume VI of the Proceedings and the increased outlay for clerical services in handling the rapidly-increasing business of the Society has resulted in a small deficit for the year ending June 15, 1907, the cash balance being $258.80, with outstanding obligations aggregating $274.80, although the financial affairs of the Society have been very carefully administered. It is estimated that the unpaid membership dues for the current fiscal year, the dues from new members and the proceeds from sales of publications will aggregate about $1,700 for the remainder of the year, which sum will probably not suffice to meet the running expenses. As foreshadowed in the last Annual Report the Society dispensed with the support of the Contributing Members for the year 1906. In view of the conditions above outlined, the Executive Committee has recently decided, however, to call on the Contributing Members for dues of the current year with the expectation that the necessity of doing so is not likely to recur in the future.

Owing to present limited financial resources the Executive Committee deems it desirable to defer the publication in a separate volume of the Standard Specification adopted by the Society.

The statistics of the year, set forth in more detailed form, are as follows:

Membership.—The membership at the last Annual Meeting was 835. Since then 156 new applications have been received and approved. The Society has suffered a loss of two members through death: George Tatnall died September 15, 1906, and Wallace C. Johnson, died December 15, 1906. The number of resignations for the year is 34, and 30 members have been dropped for arrears in dues. The total loss from all causes is 66, leaving a net gain of 90, and making the total membership at present 925.

Publications.—In addition to the annual volume of the Proceedings (Vol. VI, 712 pp.), a pamphlet of 108 pages containing the list of members and other information of a general nature, concerning the Society was issued, as well as four official circulars of information.

Technical Committees.—In pursuance of action at the last Annual Meeting a new Committee U on the Corrosion of Iron and Steel, has been organized, and the attempted organization of a Committee on Standard Specifications and Tests for Wire Rope has been abandoned.

Finances.—The somewhat unsatisfactory financial condition of the Society and the causes of the same, which are believed to be of a temporary nature only, have been previously referred to. The cash balance is $258.80, and the outstanding obligations aggregate $274.80.

ANNUAL REPORT OF THE TREASURER.

From June 15, 1906, to June 15, 1907.

RECEIPTS.

Membership Dues	$4,451 94	
Contributing Membership Dues	350 00	
Collections for account International Association	424 88	
Sale of publications	694 65	
Orders for binding	162 74	
Reprints	88 40	
Excess remittances	6 70	
Interest on deposits	10 90	
Total receipts	$6,190 21	
Cash balance June 15, 1906	495 18	
		$6,685 39

DISBURSEMENTS.

Remitted to International Association, Dues, etc.	$ 332 71	
Expenses, International Association	85 93	
Printing, engraving, binding, etc.	3,429 12	
Secretary's salary to July 1, 1906	1,500 00	
Clerical services	515 00	
Expenses, Secretary's office	269 87	
Stenographer, Ninth Annual Meeting	175 00	
Committee expenses	101 88	
Excess remittances refunded	7 08	
Total disbursements	$6,416 59	
Cash balance, June 15, 1907	268 80	
		$6,685 39

Relations with International Association for Testing Materials.—Of the 925 members of the American Society, 269 hold membership also in the International Association. The Fourth Congress of the International Association held at Brussels in September, 1906, was highly successful, but the participation of the American members was disappointingly small, both in their contributions to the Proceedings and in point of attendance. For the first time in its history the Association undertook the publication of official papers consisting principally of the reports of its technical committees in three languages. Thirty-four such reports were issued. These reports, which are of considerable scientific interest and value, were furnished to every member without additional cost. Twenty-five non-official papers, published in the original language only, with appended abstracts in two other languages, were also issued in connection with the Congress, at a total subscription price of $2.50 for the set. These papers may be obtained at the price stated, on application to the Secretary of the American Society. Application blanks for membership in the International Association may be obtained through the same source. The annual dues in the International Association are $1.50, and there is no initiation fee.

Respectfully submitted on behalf of the Executive Committee

CHARLES B. DUDLEY,
President.

EDGAR MARBURG,
Secretary-Treasurer.

REPORT OF AUDITING COMMITTEE.

PHILADELPHIA, PA., July 9, 1907.

To the Executive Committee of the American Society for Testing Materials:

We have examined the books and accounts of the Secretary and Treasurer, from January 1, 1907—the date of the last audit—to June 15, 1907, the date of the annual report of the Treasurer, and find the cash balance of $268.80 to be correct.

[Signed]

R. W. LESLEY,
J. A. COLBY,
Auditing Committee.

APPENDIX.

ABSTRACT OF MINUTES OF THE EXECUTIVE COMMITTEE.

Regular Meeting, June 23, 1906.—Hotel Chalfonte, Atlantic City, N. J. Present: Messrs. Lesley and Marburg.

In the absence of a quorum the meeting was declared informal.

The Secretary reported the receipt of 46 applications for membership duly approved, making the total membership 835.

Regular Meeting, October 6, 1906.—Engineering Building, University of Pennsylvania, Philadelphia, Pa. Present: Messrs. Dudley, Bostwick, Christie and Marburg.

The action taken at the last quarterly meeting on June 23, in the absence of a quorum, was duly approved.

The Secretary reported the receipt of 58 new applications for membership, duly approved, and one resignation, making the total membership 892.

The following action was taken on matters referred to the Executive Committee at the Annual Meeting:

1. To organize a Committee on the Corrosion of Iron and Steel.
2. To refer the subject of Standard Specifications for Ship Material to Committee A, with instructions to appoint a sub-committee on this subject.
3. To refer the recommendation of Standard Speeds for Testing Machines to Committee O with discretionary power.
4. The proposal of Committee E that funds for its investigations be obtained by subscriptions, to be solicited in the name of the Society, was approved with the understanding that the circular letters to be issued in that connection be submitted to the Executive Committee for approval.
5. The question of appointing a Committee on Chain Iron and Steel, Chains and Chain Cables, was referred to the President and Secretary for further inquiry.

The Secretary was instructed to open communication with the United States Bureau of Standards, with a view of ascertaining in what way co-operation on the part of the Society with that Bureau might be made to mutual advantage.

The question of publishing all Standard Specifications thus far adopted in the form of a separate volume was discussed, but it was decided to defer final action in this matter for the present.

The Secretary was instructed to communicate with the Chairman of Committee A to call his attention to the resolutions passed at the last Annual Meeting affecting the Standard Specifications for Steel Rails, and to recommend that every effort be made towards getting these specifications in satisfactory shape before the next Annual Meeting.

REGULAR MEETING, January 5, 1907.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, McLeod and Marburg.

The Secretary reported the receipt of 27 new applications for membership, duly approved, four resignations and the loss of one member through the death of George Tatnall on September 15, 1906, making the total membership 914.

The Secretary presented a report from the Auditing Committee, consisting of Mr. R. W. Lesley and Mr. J. A. Colby, certifying to the correctness of the books and accounts from June 15, 1906, to December 31, 1906, and to a cash balance of $33.62.

The Secretary was instructed to communicate with the Chairman of Committee A, instructing him to proceed with the appointment of a small sub-committee to consider the revision of the Standard Specifications for Steel Rails.

The Secretary announced the appointment by Mr. A. Rieppel, Chairman of Committee I of the International Association, of Mr. Walter Wood as the American member of a sub-committee of Committee I, to co-operate with the members of this sub-committee in other countries in the consideration of the question of the unification of specifications for Iron and Steel in the different countries.

Certain complications arising out of the apparent irregularity of this appointment which was made without notification of the American Member of Council and without a recommendation on the part of the American Society were discussed, and the President and Secretary were instructed to arrange, if possible, for their satisfactory adjustment.

The President announced the appointment of Prof. A. N. Talbot as a member of the International Committee on Reinforced Concrete.

The Secretary reported that the inquiries instituted in connection with the proposed organization of a Committee on Chain Iron and Steel, Chains and Chain Cables, had resulted very unsatisfactorily, and that the organization of the Committee on Standard Specifications and Tests for Wire Rope had also proved impracticable. It was accordingly decided to abandon the attempt to organize the latter committee with the concurrence of the persons who had signified their willingness to accept service on the same, and to postpone indefinitely the organization of a committee on Chain Iron and Steel, Chains and Chain Cables.

REGULAR MEETING, April 6, 1907.—Merion Cricket Club, Haverford, Pa. Present: Messrs. Dudley, Lesley, Christie and Marburg.

The Secretary reported the receipt of 23 applications for membership, duly approved, the loss of one member through the death of Wallace C. Johnson on December 15, 1906, the resignation of 26 members and the dropping of 30 members on account of arrears in dues, making the total membership 880.

The Secretary submitted letters from the International Association and from Mr. Rieppel, Chairman of Committee I, acknowledging the irregularity of the appointment of the American representative on the International Committee on Standard Specifications, and stating that the Council of the International Association had authorized the appointment of two representatives from each country concerned, the selection of the American members being left to the discretion of the American member of Council.

The President stated that he had notified the International Association and Mr. Rieppel that this action was entirely satisfactory, and that the appointments would be made later.

The Secretary reported that at the last Convention of the American Institute of Architects the following resolution had been adopted:

"That the powers of the Committee on Specifications be so enlarged that they include co-operation with the American Society for Testing Materials in the work of securing and establishing uniform specifications for building materials."

The financial status of the Society was fully discussed, and the Secretary was authorized to solicit contributions for 1907 from the Contributing Members.

It was decided that the attempt to organize Committee U on Standard Specifications and Tests for Wire Rope be abandoned.

LIST OF PUBLICATIONS.

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NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated the American Section of the International Association for Testing Materials. During this period twenty-eight (28) Bulletins were issued, which, collectively, constitute Volume I. of the Proceedings. In 1902 it was decided to publish the Proceedings in the form of annual volumes. Volume II. is the first volume of this new series.

VOLUME I.

Bulletin No. 1. Minutes of the Organization Meeting, June 16, 1898. Minutes of the Executive Committee, June 25, 1898, to February 22, 1899. Minutes of First Annual Meeting, August 27, 1898. April 1899. Pp. 1–8.

Bulletin No. 2. Provisional Program for the Second Annual Meeting. July, 1899. Pp. 9–12.

Bulletin No. 3. Officers of the American Section. Program of the Second Annual Meeting. August, 1899. Pp. 13–16.

Bulletin No. 4. The work of the International Association for Testing Materials. Annual Address by the Chairman, Professor Mansfield Merriman. September, 1899. Pp. 17–26.

Bulletin No. 5. Preliminary Report on the Present State of Knowledge Concerning Impact Tests, by Professors W. Kendrick Hatt and Edgar Marburg. October, 1899. Pp. 27–52.

Bulletin No. 6. Report of Second Annual Meeting, August 15–16, 1899. Minutes of the Executive Committee to August 16, 1899. November 1899. Pp. 53–72.

Bulletin No. 7. Minutes of the Executive Committee to January 6, 1900. Miscellaneous Announcements. January, 1900. Pp. 73–80.

Bulletin No. 8. Proposed Standard Specifications for Structural Steel for Bridges and Ships. May, 1900. Pp. 81–86.

Bulletin No. 9. Proposed Standard Specifications for Structural Steel for Buildings. May, 1900. Pp. 87–92.

Bulletin No. 10. Proposed Standard Specifications for Open-hearth Boiler Plate and Rivet Steel. May, 1900. Pp. 93–100.

Bulletin No. 11. Proposed Standard Specifications for Steel Rails. May, 1900. Pp. 101-106.

Bulletin No. 12. Proposed Standard Specifications for Steel Splice Bars. May, 1900. Pp. 107-110.

Bulletin No. 13. Proposed Standard Specifications for Steel Axles. May, 1900. Pp. 111-114.

Bulletin No. 14. Proposed Standard Specifications for Steel Tires. May, 1900. Pp. 115-118.

Bulletin No. 15. Proposed Standard Specifications for Steel Forgings. May, 1900. Pp. 119-124.

Bulletin No. 16. Proposed Standard Specifications for Steel Castings. May, 1900. Pp. 125-128.

Bulletin No. 17. Proposed Standard Specifications for Wrought Iron. May, 1900. Pp. 129-134.

Bulletin No. 18. Report of the American Branch of International Committee No. 1. May, 1900. Pp. 135-144.

Bulletin No. 19. Program of the Third Annual Meeting. Minutes of the Executive Committee, April 7, 1900. Correspondence Relating to the Representation of the American Section of the International Council. September, 1900. Pp. 145-172.

Bulletin No. 20. Progress Report of the American Branch of International Committee No. 1. October, 1900. Pp. 173-184.

Bulletin No. 21. Announcement of International Congress of 1901. Report of Third Anual Meeting, October 25-27, 1900. Minutes of the Executive Committee to January 5, 1901. Officers of the American Section for 1900-02. March, 1901. Pp. 185-214.

Bulletin No. 22. Program of the Fourth Annual Meeting. May, 1901. Pp. 215-216.

Bulletin No. 23. List of Members of the American Section. By-Laws of the American Section. June, 1901. Pp. 217-230.

Bulletin No. 24. Revised Standard Specifications for Wrought Iron. June, 1901. Pp. 231-236.

Bulletin No. 25. Report of the American Branch of International Committee No. 1. June, 1901. Pp. 237-244.

Bulletin No. 26. Letter Ballot on Proposed Standard Specifications. July, 1901. Pp. 245-246.

Bulletin No. 27. Report of Fourth Annual Meeting, June 29, 1901. August, 1901. Pp. 247-262.

Bulletin No. 28. Program of the Fifth Annual Meeting. May, 1902 Pp. 263-266.

VOLUME II.

Summary of Proceedings of the Fifth Annual Meeting.

Annual Address by the Retiring President, Henry M. Howe.

Proposed Modifications of the Standard Specifications for Steel Rails Topical Discussion.

Is it Desirable to Specify a Single Grade of Structural Steel for Bridges of Ordinary Spans? Topical Discussion.

Formal Discussion: A. P. Boller, T. L. Condron, Theodore Cooper, J. E. Greiner, John McLeod, C. C. Schneider, J. P. Snow.

Rail Temperatures. Simon Strock Martin.

Finishing Temperature and Structure of Steel Rails. Albert Sauveur.

The Relation between the Basic Open-hearth Process and the Physical Properties of Steel. Topical Discussion.

Steel Rivets. Gaetano Lanza.

The Ethics of Testing. Paul Kreuzpointner.

Standard Cement Specifications. R. W. Lesley.

The Advantages of Uniformity in Specifications for Cement and Methods of Testing. George S. Webster.

The Chemical Analysis of Cement: Its Possibilities and Limitations. Richard K. Meade.

Cement Testing in Municipal Laboratories. Richard L. Humphrey.

Tests of Reinforced Concrete Beams. W. Kendrick Hatt.

Effect of Variation in the Constituents of Cast Iron. W. G. Scott.

Present Status of Testing Cast Iron. Richard G. Moldenke.

The Need of Foundry Experience for the Proper Inspection and Testing of Cast Iron. Thos. D. West.

A Quick and Automatic Taper-Scale Test. Asa W. Whitney.

High Strength of White Iron Castings as Influenced by Heat Treatment. Alex. E. Outerbridge, Jr.

Notes on Current Specifications for Cast Iron Pipe. Walter Wood.

On the Constitution of Cast Iron. Henry M. Howe.

APPENDICES.

Appendix I. Report on the Buda-Pesth Congress. Henry M. Howe.

Appendix II. Bibliography on Impact Tests and Impact Testing Machines. W. Kendrick Hatt and Edgar Marburg.

Appendix III. Rules for Standard Tests of Materials Formulated by the German Association for Testing Materials (English Translation).

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Report of Committee A on Standard Specifications for Iron and Steel.

Report of Committee B on Standard Specifications for Cast Iron and Finished Castings.

Report of Committee C on Standard Specifications for Cement.

Report of Committee E on Preservative Coatings for Iron and Steel.

Report of Committee G on the Magnetic Properties of Iron and Steel.

Specifications for Iron and Steel Structures Adopted by the American Railway Engineering and Maintenance of Way Association, in March, 1903, with Introduction by J. P. Snow, Chairman.

Specifications for Locomotive Axles and Forgings, Recommended by a Committee of the American Railway Master Mechanics' Association in June, 1903, with Introduction by F. H. Clark, Chairman.

Specifications for Steel Rails Adopted by the American Railway Engineering and Maintenance of Way Association, in March, 1902, and the Modifications Submitted in March, 1903; William R. Webster, Chairman.

Specifications for Boiler Plate, Rivet Steel, Steel Castings, and Steel Forgings, Recommended by a Committee of the American Society of Mechanical Engineers; H. W. Spangler, Chairman.

Manufacturers' Standard Specifications as Revised in February, 1903, and Their Comparison with Other Recent Prominent Specifications. Albert Ladd Colby.

The Requirements for Structural Steel for Ship-building Purposes. Topical Discussion, opened by E. Platt Stratton.

Springs and Spring Steels. William Metcalf.

The Rolling of Piped Rails. Topical Discussion, opened by Albert Sauveur and Robert Job.

The Casting of Pipeless Ingots by the Sauveur Overflow Method. Albert Sauveur and Jasper Whiting.

Nickel Steel: Its Properties and Applications. Albert Ladd Colby.

Alternate Stresses in Bridge Members. Gustav Lindenthal.

The Constitution of Cast Iron. William Campbell.

Machine-cast Sandless Pig Iron in Relation to the Standardizing of Pig Iron for Foundry Purposes. Edgar S. Cook.

The Physical Properties of Malleable Castings as Influenced by the Process of Manufacture. Richard G. Moldenke.

Cast Iron: A Consideration of the Reactions Which Make it Valuable. Herbert E. Field.

The Importance of Adopting Standard Sizes of Test Bars for Determining the Strength of Cast Iron. Alexander E. Outerbridge, Jr.

The Demand for a Specified Grade of Cast Iron. W. G. Scott.

Cast Iron for Dynamo and Motor Frames. H. E. Diller.

The Light Aluminum Alloys. J. W. Richards

The Testing of Bearing Metals. G. W. Clamer.

The Master Car Builders' Drop-testing Machine as Installed at Purdue University. W. F. M. Goss.

Stremmatograph Tests of Unit Fiber Strains and Their Distribution in the Base of Rails under Moving Locomotives. Cars, and Trains. P. H. Dudley.

The Control of the Finishing Temperature of Steel Rails by the Thermomagnetic Selector. Albert Sauveur and Jasper Whiting.

A Direct-reading Apparatus for Determining the Energy Losses in Transformer Iron. J. Walter Esterline.

The United States Road Material Laboratory Its Aims and Methods L. W. Page and A. Cushman.

A Preliminary Program for the Timber Test Work to be Undertaken by the Bureau of Forestry, United States Department of Agriculture. W. K. Hatt.

A Brief Account of the History and Methods of the International Railway Congress. P. H. Dudley.

The Testing of Bitumens for Paving Purposes. A. W. Dow.

Soundness Tests of Portland Cement. W. P. Taylor.

Portland Cement Mortar Exposed to Cold. C. S. Gowen.

Some Observations on the Effect of Water and Combinations of Sand upon the Setting Properties and Tensile Strength of Portland and Natural Cements. E. S. Larned.

Tests on the Compressive Strength of Concrete and Mortar Cubes. C. H. Umstead.

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The Influence of Specifications on Commercial Products—Annual Address by the President, Charles B. Dudley.

Report of Committee A on Standard Specifications for Iron and Steel. Discussion.

Report of Committee B on Standard Specifications for Cast Iron and Finished Castings.

1. Proposed Standard Specifications for Foundry Pig Iron.
   Chemical Specifications for Pig Iron. B. F. Fackenthal.
   Specifications for Cast Iron and Finished Castings. Richard Moldenke.
2. Proposed Standard Specifications for Cast Iron Pipe and Special Castings.
3. Proposed Standard Specifications for Locomotive Cylinders.
4. Proposed Standard Specifications for Cast Iron Car Wheels.
5. Proposed Standard Specifications for Malleable Castings.
6. Proposed Standard Specifications for Gray Iron Castings.

Standard Specifications for Foundry Pig Iron, as adopted November 14, 1904.

Report of Committee C on Standard Specifications for Cement.

Report of Committee E on Preservative Coatings for Iron and Steel.

Report of Committee G on the Magnetic Testing of Iron and Steel.

Report of Committee H on Standard Tests for Road Materials.

Specifications for Steel Rails, American Railway Engineering and Maintenance of Way Association, as Amended and Adopted in March, 1904; Wm. R. Webster, Chairman.

Specifications for Iron and Steel Structures, American Railway Engineering and Maintenance of Way Association, as Amended and Adopted in March, 1904; J. P. Snow, Chairman.

Comparison of the Specifications for Axles and Forgings, Proposed by Committees of the American Railway Master Mechanics' Association and the American Society of Mechanical Engineers, with the Standard Specifications Adopted by the American Society for Testing Materials. H. V. Wille.

Alloy Steels. William Metcalf.

A Brief Review of the Status of Testing in the United States. Gaetano Lanza.

The Early Use of 60,000-pound Steel in the United States. Samuel Tobias Wagner.

The Classification of Iron and Steel. Albert Sauveur.

A Proposed Test for Detecting Brittleness in Structural Steel. J. P. Snow.

Appendix. Experimental Studies of the Causes of Brittleness of Steel. Ch. Fremont.

Tests for Detecting Brittle Steel. Wm. R. Webster.

Tensile Impact Tests of Steel. W. K. Hatt.

Staybolt Iron and Machine for Making Vibratory Tests. H. V. Wille.

Bending Moments in Rails. P. H. Dudley.

The Desirability of a Uniform Speed for Commercial Testing. Paul Kreuzpointner.

Cast Iron: Strength, Composition, Specifications. W. J. Keep.

Pig Iron Feasts and Famines: Their Causes and How to Regulate Them George H. Hull.

Structure of Alloys. William Campbell.

A New Chuck for Holding Short Test Pieces. T. D. Lynch.

The Commercial Testing of Sheet Steel for Electrical Purposes. C. E. Skinner.

Permeability of Cast Steel. H. E. Diller.

Specifications for Air-Brake Hose. Max H. Wickhorst.

The Effects of Preservative Treatments on the Strength of Timber. F. A. Kummer.

Results of an Investigation Concerning Causes of Durability of Paints for Structural Work. Robert Job.

Preservative Coatings for Iron and Steel. Cyril de Wyrall.

Some Statistics of the Cement Industry in America. R. W. Lesley.

Practical Cement Control. Charles W. McKenna.

Some Possible By-Products in the Portland Cement Industry. Clifford Richardson.

Some Notes on the Boiling Test for Cement. Frederick H. Lewis.

Tests of Reinforced Concrete Beams: A. N. Talbot, F. E. Turneaure, Edgar Marburg.

Discussion of the three preceding papers.

The Mechanical Defects of Sieves Used in Determining the Fineness of Cement. E. W. Lazell.

Some Attempts to Limit the Personal Equation in Cement Testing. W. A. Aiken.

VOLUME V.

Summary of Proceedings of the Eighth Annual Meeting.

The Testing Engineer—Annual Address by the President, Charles B. Dudley

Report of Committee A on Standard Specifications for Iron and Steel, embodying recommendations for the revision of the Standard Specifications for (1) Structural Steel for Bridges, (2) Steel Rails, (3) Steel Castings, (4) Steel Axles and (5) Steel Forgings.

Summary of Action on Report of Committee A on Standard Specifications for Iron and Steel.

Standard Specifications for Structural Steel for Bridges.

Standard Specifications for Steel Castings.

Standard Specifications for Steel Axles.

Standard Specifications for Steel Forgings.

Report of Committee B on Standard Specifications for Cast Iron and Finished Castings, embodying the proposed Standard Specifications for (1) Car Wheels and (2) Gray Iron Castings.

Report of Committee C on Standard Specifications for Cement.

Report of Committee E on Preservative Coatings for Iron and Steel.

Report of Committee G on the Magnetic Testing of Iron and Steel.

Report of Committee H on Standard Tests for Road Materials.

Report of Committee I on Reinforced Concrete.

Report of Committee K on Standard Methods of Testing.

Report of Committee M on Standard Specifications for Staybolts.

Report of Committee N on Standard Tests for Lubricants.

Report of Committee O on Uniform Speed in Commercial Testing.

Report of Committee P on Fireproofing Materials.

Report of Committee Q on Standard Specifications for the Grading of Structural Timber.

Report of Committee R on Boiler Inspection.

Some Causes of Failure of Rails in Service—Robert Job.

Rail Sections as Engineering Structures—P. H. Dudley.

Influence of Methods of Piling Staybolt Iron on Vibratory Tests—H. V. Wille.

A Preliminary Report on the Effect of Combined Stresses on the Elastic Properties of Steel—E. L. Hancock.

A Comparison of Standard Methods of Testing Cast Iron—Richard Moldenke.

The Thermit Process in American Practice—E. Stuetz.

Pig Iron Grading by Analysis—Hambden Buel.

Hard Cast Iron: The Theory of One of its Causes—Henry Souther.

Plan and Scope of the Proposed Investigation of Structural Materials Under the Auspices of the U. S. Geological Survey—J. A. Holmes and Richard L. Humphrey.

A Laboratory Course in Testing Materials of Construction—W. K. Hatt.

An Elementary Course in Properties of Materials—G. L. Christensen.

A Large Hydraulic Testing Machine for Uniform Loads—Robert A. Cummings.

Specifications for Cotton Tapes for Electrical Purposes—R. D. DeWolf.

The Rattler Test for Paving Brick as a Safe Method of Disclosing the Limit of Permissible Absorption—Edward Orton, Jr.

Normal Consistency Tests of Neat Cement—R. S. Greenman.

Economical Mold for Forming Compressive Test Pieces for Concrete—Clifford Richardson and C. N. Forrest.

Low-pulling, Early-stage Portland Cement *vs.* the Ordinary Early-strength-developing Product—W. A. Aiken.

Investigation of the Effect of Heat Upon the Crushing Strength and Elastic Properties of Concrete—Ira H. Woolson.

British Standard Specifications for Portland Cement, with Introduction—R. W. Lesley.

Impact Tests of Asphalt Paving Mixtures—Clifford Richardson and C. N. Forrest.

The Collective Portland Cement Exhibit and Model Testing Laboratory of the Association of American Portland Cement Manufacturers and the Results of Tests at the Louisiana Purchase Exposition, St. Louis, Mo.—Richard L. Humhprey.

Proper Methods in Conducting Painting Tests—G. W. Thompson.

The Practicability of Establishing Standard Specifications for Preservative Coatings for Steel—Topical Discussion.

Protection of Iron and Steel Structures by Means of Paper and Paint—Louis H. Barker.

What is the Best Method of Painting Steel Cars? Frank P. Cheesman.

The Effect of Electricity on Paint—James C. Blanch.

Ludwig von Tetmajer—Memoir.

VOLUME VI.

Summary of Proceedings of the Ninth Annual Meeting.

The American Society for Testing Materials—Its Past and Future, Address by the Vice-President, Robert W. Lesley.

Report of Committee A on Standard Specifications for Iron and Steel, embodying recommendations for the revision of the Standard Specifications for Steel Rails.

Proposed Standard Specifications for Steel Rails.

Report of Committee B on Standard Specifications for Cast Iron and Finished Castings.

Report of Committee E on Preservative Coatings for Iron and Steel.

Report of Committee F on the Heat Treatment of Iron and Steel.

Report of Committee G on the Magnetic Testing of Iron and Steel.

Report of Committee H on Standard Tests for Road Materials.

Report of Committee I on Reinforced Concrete.

Report of Committee J on Standard Specifications for Coke.

Report of Committee K on Standard Methods of Testing.

Report of Committee L on Standard Specifications and Tests for Clay and Cement Sewer Pipes.

Report of Committee M on Standard Specifications for Staybolt Iron.

Report of Committee O on Uniform Speed in Commercial Testing.

Report of Committee P on Fireproofing Materials.

Report of Committee Q on Standard Specifications for the Grading of Structural Timber.

Report of Committee R on Uniform Specifications for Boilers.

Report of Committee S on Waterproofing Materials.

Report of Committee T on the Tempering and Testing of Steel Springs and Standard Specifications for Spring Steel.

The Corrosion of Structural Steel as Affected by its Chemical Composition—J. P. Snow.

The Electrolytic Corrosion of Structural Steel—Max. Toch.

The Relative Corrosion of Wrought Iron and Steel—H. M. Howe.

The Corrosion of Iron and Steel—General Discussion.

Standard Specifications for Ship Material—General Discussion.

Experiments on the Segregation of Steel Ingots in its Relation to Plate Specifications—C. L. Huston.

An Experimental Double-muffle Gas Heating Furnace, for Studying the Laws of the Heat Treatment of Steel—H. M. Howe.

On the Heat Treatment of Some High-carbon Steels—William Campbell.

The Burning, Overheating and Restoring of Nickel Steel—G. B. Waterhouse.

The Beneficial Effect of Adding High-grade Ferro-silicon to Cast Iron —A. E. Outerbridge, Jr.

Tension Tests of Steel Angles—F. P. McKibben.

Fire-box Steel—Failures and Specifications—Max H. Wickhorst,

The Effect of Combined Stresses on the Elastic Properties of Iron and Steel—E. L. Hancock.

Tests of Metals in Reverse Torsion—E. L. Hancock.

A Complete Magnetic Testing Equipment—J. Walter Esterline.

Methods of Testing Cements for Waterproofing Properties—W. P. Taylor.

Work Done in the Structural Materials Testing Laboratories, U. S. Geological Survey, During the Year Ending June 30, 1906—R. L. Humphrey.

Concrete Column Tests at Watertown Arsenal—J. E. Howard.

The Consistency of Concrete—S. E. Thompson.

Notes on Compression Tests of Cement—W. P. Taylor.

The Determination of the Specific Gravity of Cements—R. K. Meade.

Some Sand Experiments Relating to Per Cent. of Voids and Tensile Strength of Cement Mortars—J. Y. Jewett.

Some Tests of Reinforced Concrete Beams—Gaetano Lanza.

Tests of Reinforced Concrete Beams—C. J. Tilden.

Investigation of the Thermal Conductivity of Concrete and the Effect of Heat upon its Strength and Elastic Properties—Ira H. Woolson.

A New Device for the Mechanical Analysis of Concrete Aggregates —C. N. Forrest.

The Purdue University Impact Machine—W. K. Hatt and W. P. Turner.

New Features of Two Large Testing Machines—W. C. DuComb, Jr.

The Operations of the Fuel Testing Plant of the U. S. Geological Survey at St. Louis, Mo., from May 1, 1905, to July 1, 1906—J. A. Holmes.

Practical Testing and Valuation of Japan—Robert Job.

Relation Between Some Physical Properties of Bitumens and Oils—A. W. Dow.

The Proximate Composition and Physical Structure of Trinidad Asphalt, with Special Reference to the Behavior of Mixtures of Bitumen and Fine Mineral Matter—Clifford Richardson.

The Development of the Test for the Cementing Value of Road Materials—Allerton S. Cushman.

Notes on the Hardness and Abrasion Tests of Road Materials—P. L. Wormeley, Jr.

Memoirs of Deceased American Investigators Who Have Contributed in a Marked Degree to the Advance of the Testing of Materials —Gaetano Lanza.

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STANDARD SPECIFICATIONS

ADOPTED BY THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

NOTE:—The formulation and adoption of Standard Specifications for the various materials of engineering is one of the important functions of the Society. These specifications are revised from time to time to meet changed conditions.

The following complete list of Standard Specifications, in their latest revised form, is here given for convenience of reference:

1. Standard Specifications for Structural Steel for Bridges, Vol. V, pp. 48–52.
2. Standard Specifications for Structural Steel for Ships, Vol. I, pp. 81–86, Bulletin, No. 8.
3. Standard Specifications for Structural Steel for Buildings, Vol. I, pp. 87–92, Bulletin, No. 9.
4. Standard Specifications for Open-Hearth Boiler Plate and Rivet Steel, Vol. I, pp. 93–100, Bulletin, No. 10.
5. Standard Specifications for Steel Rails, Vol. I, pp. 101–106, Bulletin, No. 11.
6. Standard Specifications for Steel Splice Bars, Vol. I, pp. 107–110, Bulletin, No. 12.
7. Standard Specifications for Steel Axles, Vol. V, pp. 56–58.
8. Standard Specifications for Steel Tires, Vol. I, pp. 115–118, Bulletin, No. 14.
9. Standard Specifications for Steel Forgings, Vol. V, pp. 59–62.
10. Standard Specifications for Steel Castings, Vol. V, pp. 53–55.
11. Standard Specifications for Wrought Iron, Vol. I, pp. 231–236, Bulletin, No. 24.

12. Standard Specifications for Foundry Pig Iron, Vol. IV, pp. 103–104.
13. Standard Specifications for Cast Iron Pipe and Special Castings, Vol. IV, pp. 57–66.
14. Standard Specifications for Locomotive Cylinders, Vol. IV, pp. 69–70.
15. Standard Specifications for Cast Iron Car Wheels, Vol. V, pp. 65–70.
16. Standard Specifications for Malleable Castings, Vol. IV, pp. 95–96.
17. Standard Specifications for Gray Iron Castings, Vol. V, pp. 71–74.
18. Standard Specifications for Cement, Vol. IV, pp. 107–110.
19. Standard Specifications for Steel Rails, Vol. VII, pp. 44–47.
20. Standard Test for Fireproof Floor Construction, Vol. VII, pp. 179–180.
21. Standard Specifications for Structural Timber, Vol. VII, pp. 187–192.

INTERNATIONAL
ASSOCIATION FOR TESTING MATERIALS.

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Communications for the International Association should be directed to the International Association for Testing Materials, Nordbahnstrasse 50, Vienna, II, Austria.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

BY-LAWS.

Adopted at the Buda-Pesth Congress, 1901

SECTION 1. The Association shall be called "THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS."

SEC. 2. The objects of the Association are: the development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for this purpose.

These objects will be furthered:

1. By the Congresses and other meetings of the Association.
2. By the publication of an official Journal.
3. By any other means that may appear desirable.

SEC. 3. The funds necessary for carrying out the purposes mentioned in Section 2 will be raised by

1. The annual subscriptions of members.
2. Profits from the official Journal.
3. Other contributions.

SEC. 4. Any person may become a member upon being proposed by two members of the Association.

Official bodies and technical societies can be elected directly on their sending in their application for membership.

Applications for membership must be sent in writing to the President or to a member of the Council.

Resignations of membership must be sent in the same way.

SEC. 5. It is the duty of every member to further the interests of the Society to the best of his ability.

Every member is required to pay an annual subscription of at least 6 Mks.=6 shillings=$1.50.*

The Council is authorized to increase the annual subscription in order to cover extraordinary expenses incurred in the interests of the Association.

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* Subscriptions are to be paid to the duly appointed collectors in each country, the card of membership serving as a receipt. Subscriptions not paid by the first of July are collected through the post-office.

Sec. 6. Every member has the right to obtain the Journal of the Association, during the period for which his subscription has been paid, on paying the fixed reduced price.*

Sec. 7. The Association will hold a Congress, as a rule, every second year.

The arrangements for the Congresses will be discussed at general meetings and in meetings of the different sections.

Sections will be formed for the different groups of materials as may be considered necessary.

At present there are three sections:

I. Metals.
II. Natural and artificial building stones, cements and mortars.
III. Other materials of technical value.

Any special questions relating to the subjects of the different sections will be considered at sectional meetings.

The members assisting at the sectional debates, under the presidency of a member of the Council, will appoint the governing bodies of the different sections.

The results of the deliberations of the different sections must be communicated at a general meeting which will pass resolutions embodying the proposals of the sections.

Reports of Commissions, proposals of the Council and other matters to be laid before the Congress, will be printed in German, French and English, and will be sent (in the language preferred) to all members who have announced their intention of taking part in the Congress, within fourteen days before the meeting of the Congress, if possible.

The decisions of the Congress will be printed in all three languages and sent to all members of the Association.

Sec. 8. The Council of the Association will transact all necessary business connected with the Association.

The Council will consist of the President and the duly elected members.

Every country represented in the Association by at least twenty members has the right to elect one member in the Council. For those countries where the number of members is not twenty, the Council will appoint a Mandatary who will take part in the Council meetings with voting powers.

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* The reduced price has been fixed at 10 Mks.= 10 shillings = $2.50. This sum may be sent in with the subscriptions. The yearly volumes begin on January 1.

The President will be elected by the Congress, the Council by the members belonging to the different countries.

Till such election has taken place the former members of the Council remain in office.

The names of proposed new members of the Council have to be communicated to the President before each Congress.

The two Vice-Presidents will be elected by the Council from among its own members.

The Council has the power to elect past Presidents as permanent members of Council.

The Council is entitled to transact business when it has been duly called together according to rule and when the President or one of the Vice-Presidents is present.

Members of the Council may be re-elected.

If a member of the Council resigns during his term of office, the President shall immediately direct the election of a substitute by the members belonging to the country in question.

In the event of the death or resignation of the President, the Council will appoint one of its members to carry on the presidential duties till the next Congress.

The term of office of the Council lasts from one Congress till the next.

SEC. 9. The business of the Association will be attended to by a salaried General-Secretary under the direction of the President.

The members of the Council will attend to the business of the Association in the country which they represent.

SEC. 10. The resolutions of the Congresses on technical questions merely serve to express the opinion of the majority. They are therefore in the form of recommendations and are in no way binding.

SEC. 11. The resolutions of the Congresses can only be carried if at least three-fourths of the recorded votes are in favor of them. Every member of the Association present, as well as every representative of official bodies and technical societies, has one vote.

The rights and duties of a member of the Association are not altered by the fact of his belonging at the same time to a national or other Association which Association is itself a member of the International Association.

SEC. 12. The technical problems to be considered by the Association will be decided upon by the Congresses and by the Council and will be duly referred to commissions or reporters appointed by the Council.

Sec. 13. The Council draws up its own regulations according to the By-Laws of the Association and to the needs which may from time to time present themselves.

Sec. 14. In the event of the Association being dissolved any funds belonging to it will be handed over to the "International Red Cross Association."

THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Technical Problems, Committees* and Referees.

As constituted in September, 1906.

SECTION A.

METALS.

Problem 1.—On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Rieppel Aeussere Cramer-Klettstrasse 12, Nuremburg, Germany.

Vice-Chairman, G. Alpherts, Koninginnegracht 66, Hague, Holland.

American Members, James Christie, Carnegie Steel Company, represented by W. A. Bostwick; Franklin Institute, represented by A. E. Outerbridge, Jr., Paul Kreuzpointner, R. Moldenke, W. R. Webster, Walter Wood.

Problem 2.—To establish methods of inspection and testing for determining the uniformity of individual shipments of iron and steel. (Proposed at the Stockholm Congress, 1897.)

Committee:

Chairman, W. Ast, Nordbahnhof, Vienna, Austria.

Vice-Chairman (office vacant).

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* The names of only the Chairmen, the Vice-Chairmen, and American Members of International Committees are here given.

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American Members, Booth, Garrett and Blair, Thos. Gray, Gus. C. Henning, Paul Kreuzpointner, A. A. Stevenson, W. R. Webster, Albert Sauveur.

Problem 4.—Methods for testing welds and weldability. (Proposed at the Zurich Congress, 1895.)
Referee, R. Krohn, Danzig, Germany.

Committee:

Chairman, W. Rayl, Nordbahnstrasse 50, Vienna, II, Austria.
Vice-Chairman, A. Sailler, Favoritenstrasse 20, Vienna, IV, Austria.
American Members, M. H. Wickhorst, H. V. Wille.

Problem 6.—On the most practical methods of polishing and etching for the macroscopic study of iron and steel. (Proposed at the Zurich Congress, 1895.)
Referee, E. Heyn, Carmerstrasse 15, Charlottenburg, Germany.

Problem 25.—To establish uniform methods of testing cast iron and finished castings. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, R. Moldenke, Watchung, N. J.
American Members, Alex. E. Outerbridge, Jr., Albert Sauveur Thos. D. West.

Problem 26.—Tests with notched bars for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, Ed. Sauvage, Rue Eugène Flachat 14, Paris, France.

Problem 27.—Ball-pressure tests for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)

Referees, J. A. Brinell, Chief Engineer, Jernkontoret, Stockholm, Sweden; G. Dillner, Director Royal Laboratory for Testing Materials, Stockholm, Sweden.

Problem 28.—The consideration of the magnetic and electric properties of materials in connection with their mechanical testing. (Proposed at the Buda-Pesth Congress, 1901.)

Referees, K. Hochenegg, Techn. Hochshule, Karlsplatz, Vienna, IV, Austria; M. von Hoor Tempik, Kgl. techn. Hochschule, Buda-Pesth, Hungary.

Problem 36.—Macroscopic examination of iron. (Resolution of Council, 1903.)

Referee, W. Ast, Nordbahnstrasse 50, Vienna, Austria.

Problem 37.—Microscopic examination of iron. (Resolution of Council, 1903.)

Referee, F. Osmond, 83 Boulevard de Courcelles, Paris, France.

SECTION B.

NATURAL AND ARTIFICIAL BUILDING STONES AND THEIR CEMENTS.

Problem 7.—On the relation of chemical composition to the weathering qualities of building stones; the influence of smoke, especially sulphurous acid on building stones; the weathering qualities of roofing slates. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Hanisch, Schellinggasse 13, Vienna, I, Austria.
Vice-Chairman, P. Larivière, Quai Jemmapes 170, Paris, France.
American Member, Mansfield Merriman.

Problem 9.—On rapid methods for determining the strength of hydraulic cements. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, F. Berger, Rathhaus, Vienna, I, Austria.
Vice-Chairman (office vacant).
American Members, W. W. Maclay, Chas. McKenna.

Problem 10.—To digest and evaluate the resolutions of the conferences of 1884–1893 concerning the adhesive qualities of hydraulic cements.
Referee, R. Feret, Boulogne-sur-Mer, France.

Problem 11.—To establish methods for testing puzzolanas with the object of determining their value for mortars. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, G. Herfeldt, Andernach, Germany.
Vice-Chairman, C. Segré, Ancona, Italy.
American Members, A. Lundteigen.

Committee:

Chairman, E. Candlot, rue d'Edimbourg 18, Paris, France.
Vice-Chairman, N. Lamine, Zabalkansky 9, St. Petersburg, Russia.
American Members, Spencer B. Newberry, Clifford Richardson.

Problem 13.—On the normal consistency of cement mortars for test specimens. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Greil, Rathhaus, Vienna, I, Austria.
Vice-Chairman (office vacant).
American Member, R. L. Humphrey.

Problem 29.—Determination of the liter weight of cement. The strength of neat hydraulic cements. Determination of a standard sand. (Proposed at the Buda-Pesth Congress, 1901.)
Referees, N. Belelubski, Rue Serpuchowskaja 4, St. Petersburg, Russia; F. Schuele, Eidg. Polytechnikum, Zurich, Switzerland.

Problem 30.—Determination of the simplest method for the separation of the finest particles in Portland cement by liquid and air processes. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, M. Gary, Kgl. mech.-techn. Materialprüfungsamt Charlottenburg, Germany.

Problem 31.—On the behavior of cements in sea water. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, H. Le Chatelier, Place du College de France 9, Paris, France.

Problem 32.—On accelerated tests of the constancy of volume of cements. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, Bertram Blount, Broadway, Westminster, London, S. W., England.
Vice-Chairman (office vacant).
American Members, R. W. Lesley, Spencer B. Newberry.

Problem 33.—On the influence of the proportion of water and sand on the strength of Roman and other cements. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, The Hungarian Society for Testing Materials, Buda-Pesth, Hungary.

SECTION C.

OTHER MATERIALS.

Problem 17.—On methods of testing tile pipes. (Proposed at the Stockholm Congress, 1897.)
Referee, M. Gary, Kgl. Materialprüfungsamt Charlottenburg, Germany.

Problem 18.—On the methods of testing the protective power of paints used on metallic structures. (Proposed at the Zurich Congress, 1895.)
Referees, Albert Grittner, Kobanyai ut 30, Buda-Pesth, Hungary; E. Ebert, Centralbahnhof, Munich, Germany.

Problem 19.—On uniform methods for testing lubricants. (Proposed at the Zurich Congress, 1895.)
Referee, N. Petroff, Zagorodny 70, St. Petersburg, Russia.

Problem 23.—On uniform methods for compression tests of wood.

Committee:

Chairman, Prof. A. Schwappach, Eberswalde, Germany.
Vice-Chairman, A. Wykander, Goeteborg, Sweden.

Problem 35.—Study of the methods of testing caoutchouc. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, E. Camerman, Rue Philippe Le Bon 73, Brussels, Belgium.
Vice-Chairman (office vacant).

SECTION D.

MISCELLANEOUS SUBJECTS.

Problem 22.—Considering that the resolutions formed by the International Conferences of Munich, Dresden, Berlin, Vienna and Zurich, for the purpose of attaining unity in the methods of testing materials, and the report of the Committee of the American Society of Mechanical Engineers do not agree in many points with the decisions arrived at by the French commission, it is proposed that the Council appoint a commission which shall prepare a report upon these differences, and proposal for ways and means of abolishing them.

Committee:

Chairman, N. Belelubski, Rue Serpouchowskaya 4, St. Petersburg, Russia.
Vice-Chairmen, A. Martens, Kgl. Materialprüfungsamt, Charlottenburg, Germany; E. Sauvage, l'Ecole des Mines, Paris, France.
American Members, Albert Ladd Colby, Gus. C. Henning, R. Moldenke, George F. Swain, George S. Webster, W. R. Webster, Walter Wood.

Problem 24.—On uniform nomenclature of iron and steel. (Resolution of Council, February 3, 1901.)

Committee:

Chairman, H. M. Howe, 27 West Seventy-third street, New York. N. Y.

Vice-Chairmen, L. Lévy, Rue de La Rochefoucauld 19, Paris, France; D. Tschernoff, Rue Pessatschenaia 25, St. Petersburg, Russia.

Secretary, Albert Sauveur, 446 Tremont street, Boston, Mass.

Problem 34.—Fixing a uniform definition and nomenclature of the bitumens. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, G. Lunge, Eidg. Polytechnikum, Zurich, Switzerland.

Vice-Chairman, Jenoe Kovacs, Tataros (Post Mezoe Telegd), Hungary.

American Members, A. W. Dow, Clifford Richardson.

NEW PROBLEMS.

At the Fourth Congress (Brussels, 1906) it was decided to appoint commissions to study the following problems:

1. The Principles of Specifications for Copper.
2. The Principles of Specifications for Oils for Technical Purposes.
3. The Unification of Specifications for Gypsum.

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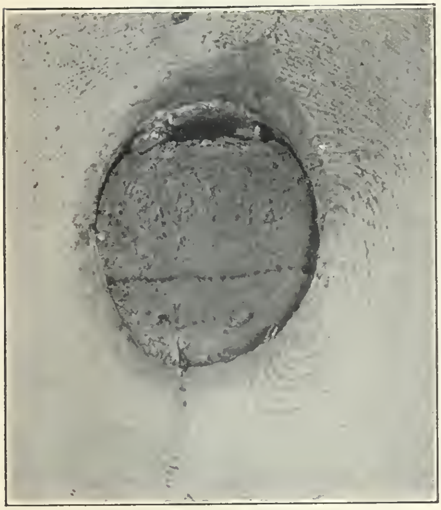


FIG. 1.—Loose Knot.

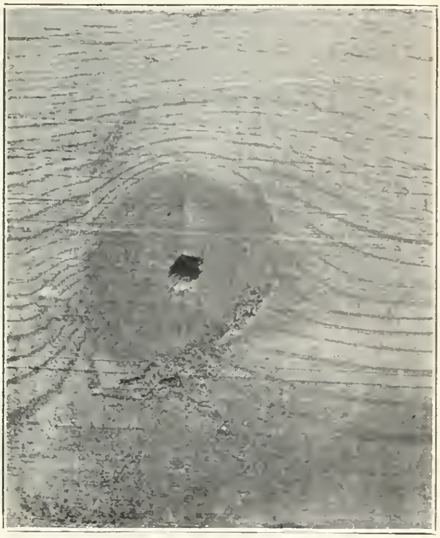


FIG. 2.—Pith Knot.

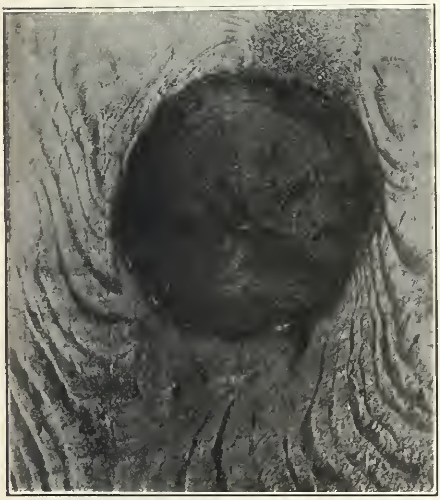


FIG. 3.—Encased Knot.

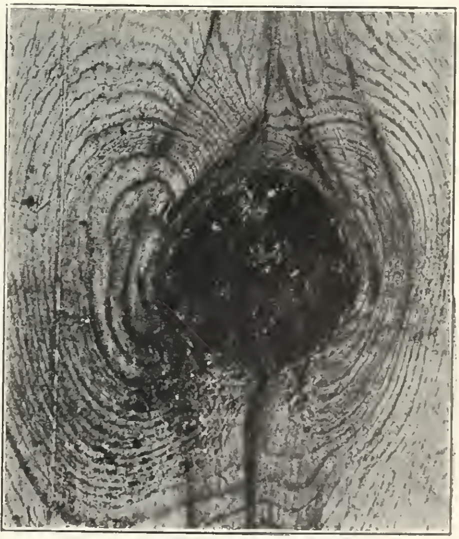


FIG. 4.—Rotten Knot.

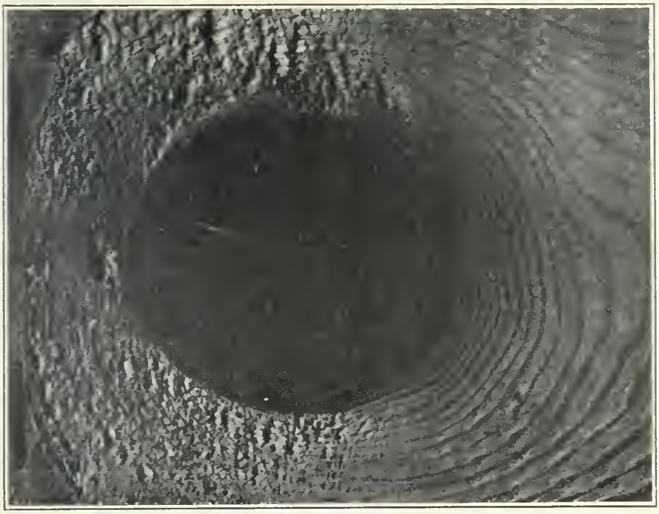


FIG. 6.—Standard Knot.

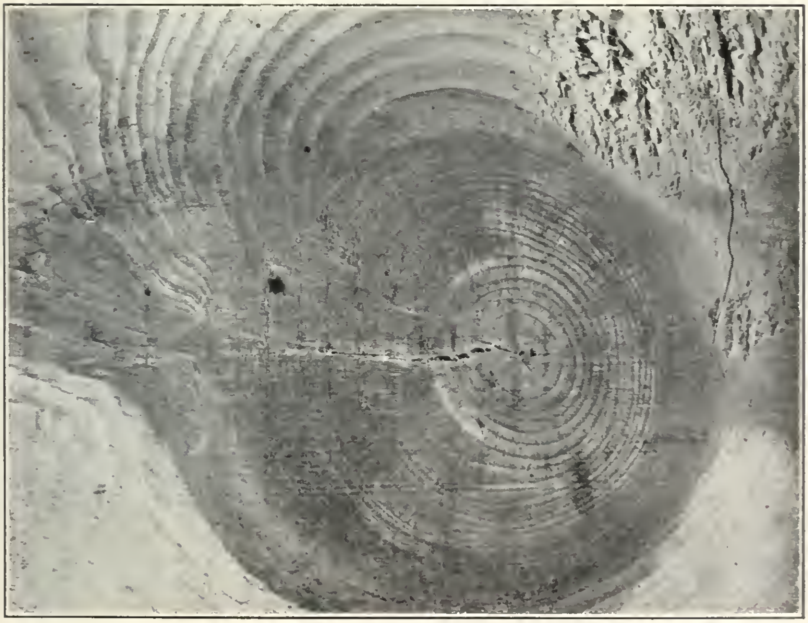


FIG. 7.—Large Knot.

PLATE III.
PROC. AM. SOC. TEST. MATS.
VOLUME VII.
STANDARD SPECIFICATIONS FOR STRUCTURAL TIMBER.

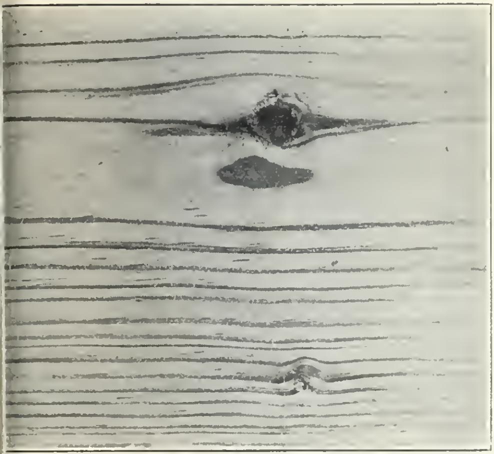


FIG. 5.—Pin Knot.

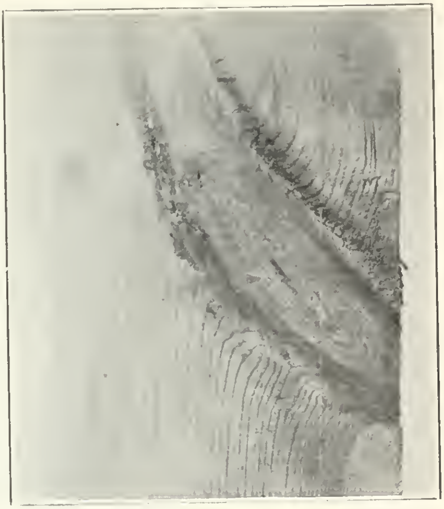


FIG. 8.—Spike Knot.

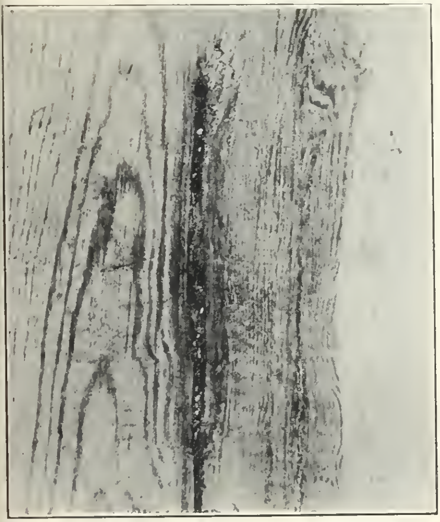


FIG. 9.—Pitch Pocket

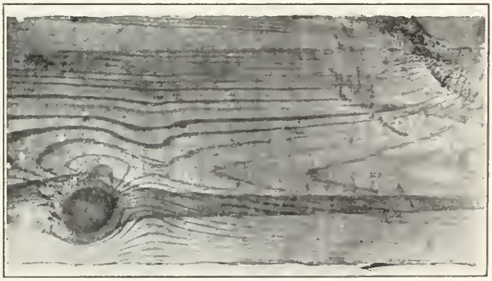


FIG. 10.—Pitch Streak.

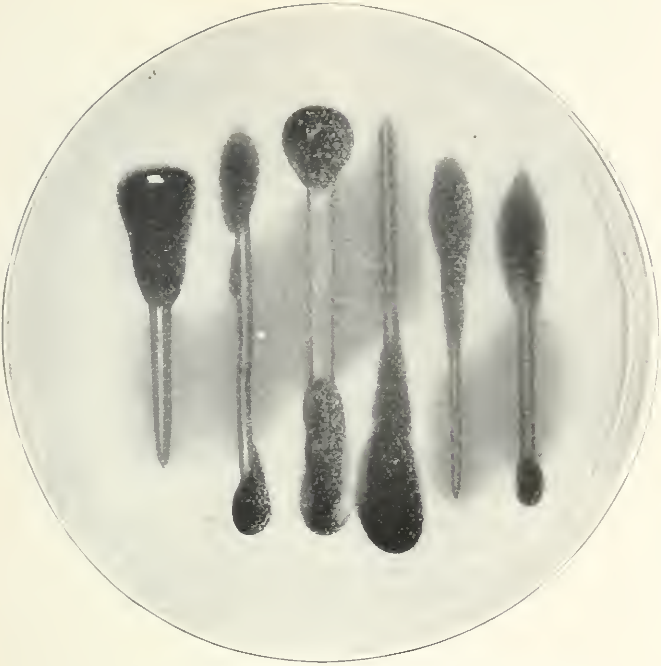


FIG. 1.—Iron and Steel Nails in Ferroxyl Reagent.

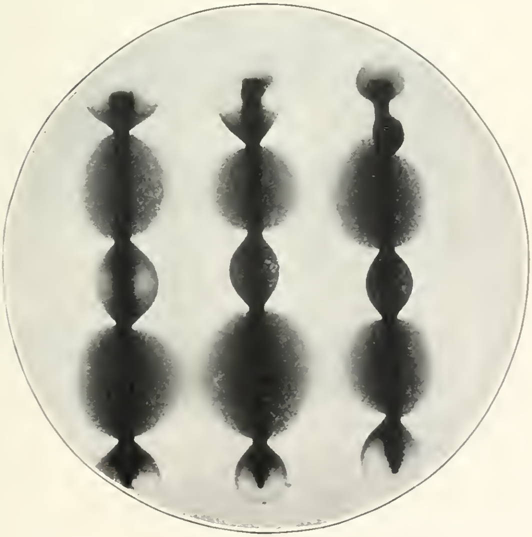


FIG. 2.—Steel Wire Nails in Ferroxyl Reagent.

PLATE V.
PROC. AM. SOC. TEST. MATS.
VOLUME VII.
CUSHMAN ON CORROSION OF IRON.

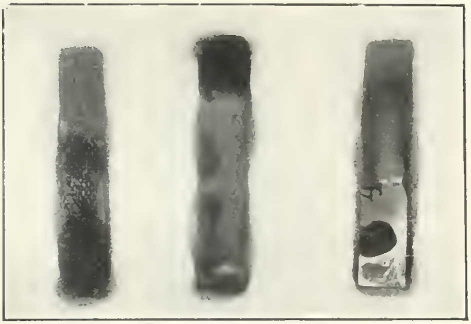


FIG. 3.—Wrought Iron, Charcoal Iron, and Steel in Ferroxyl Reagent.

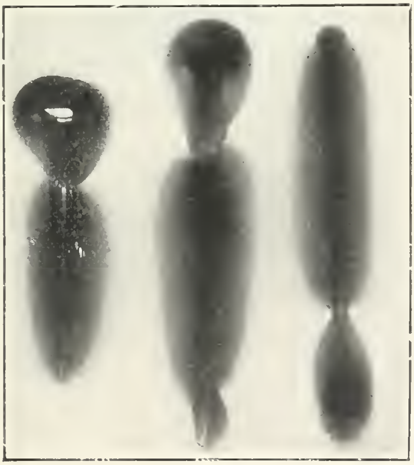


FIG. 4.—Steel Nails in Ferroxyl Reagent.

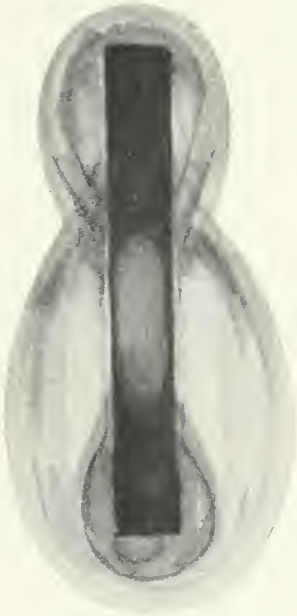


FIG. 5—Strips of Steel in "Ferroxyl" jelly, showing frequent change and reversal of poles, thus leading to general superficial rusting of its whole surface.

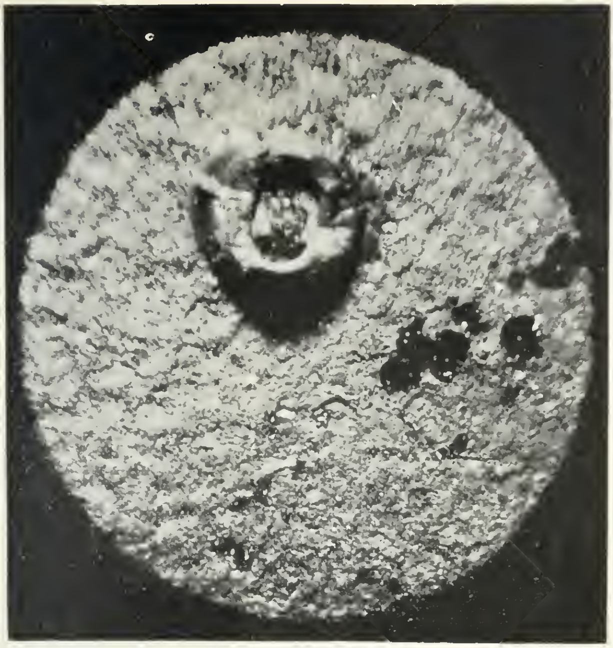


FIG. 6.—Formation of Crater with Pitting Effect in Center. (Enlarged 45 Diameters.)

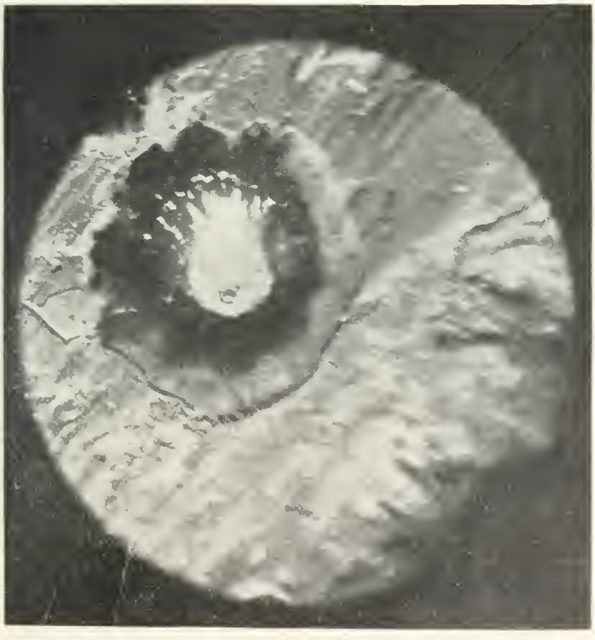


FIG. 7.—Formation of Cone with Pitting Effect in Surrounding Area. (Enlarged 45 Diameters)

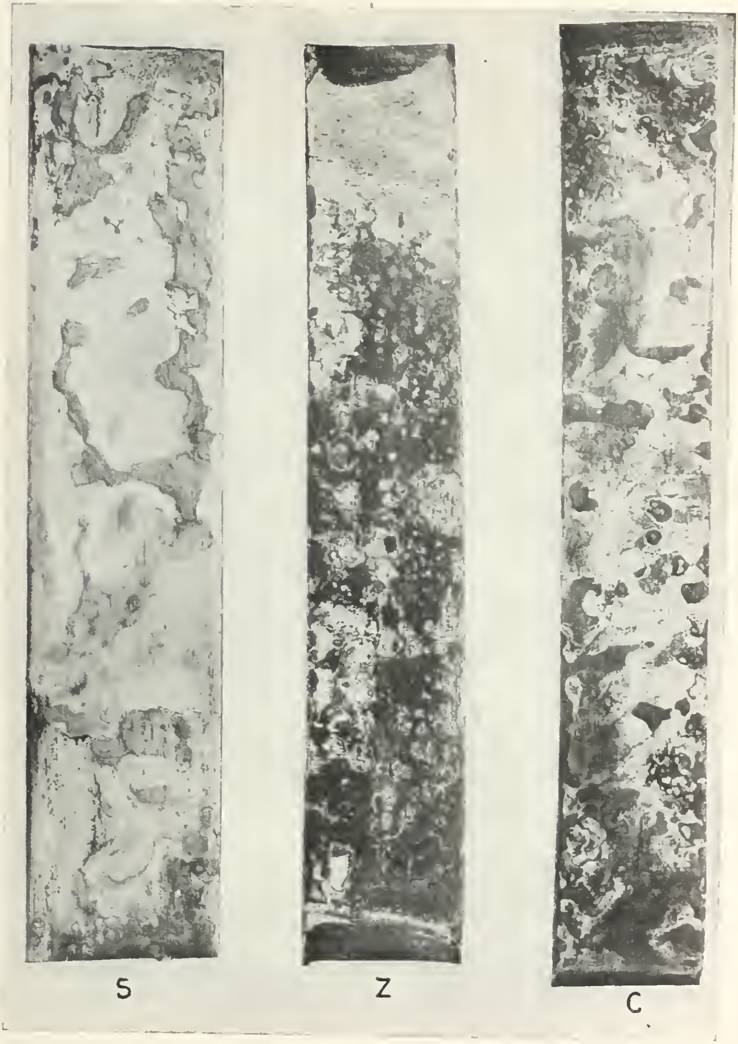


FIG. 8.—Etching Effect Produced on Polished Surfaces of Iron and Steel by Immersion in Ferroxyl Reagent. S, Bessemer Steel; Z, Puddled Wrought Iron; C, Charcoal Iron.

Plate IX.
Proc. Am. Soc. Test. Mats.
Volume VII.
Cushman on Corrosion of Iron.

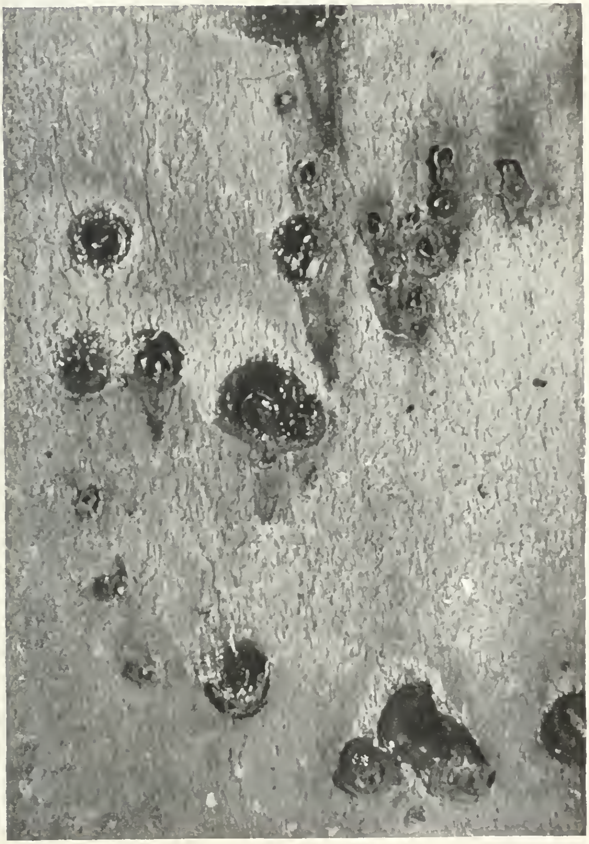


Fig. 9.—Photographed Rust Spots on the Surface of Iron.

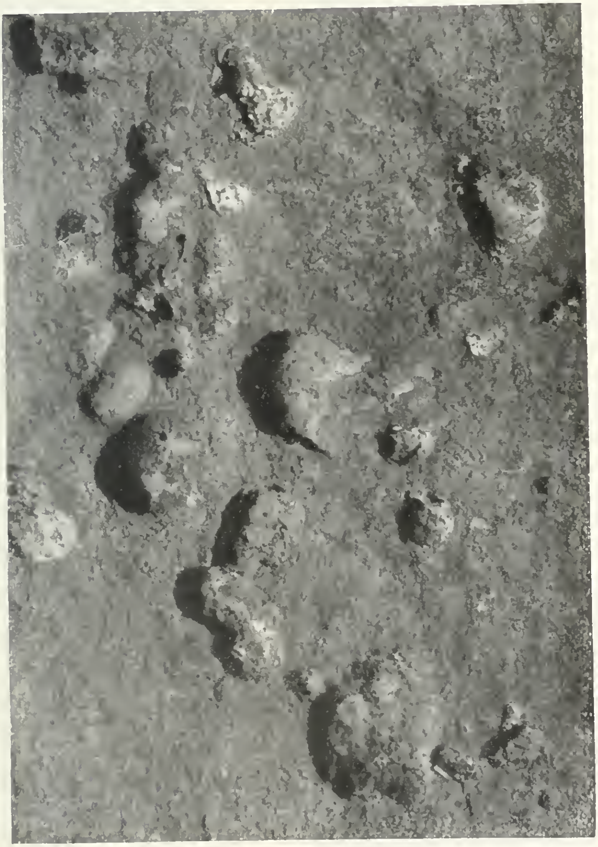
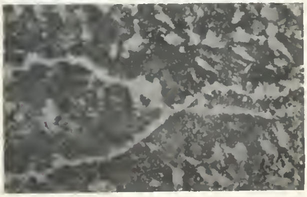


FIG. 10.—Pitmarks on the Surface of a Boiler Tube.

PLATE XI.
PROC. AM. SOC. TEST. MATS.
VOLUME VII.
CAMPBELL ON HEAT TREATMENT OF STEEL.

As cast — As rolled — Cooled in air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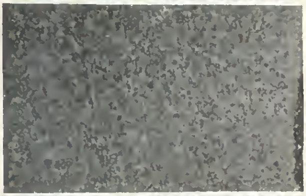
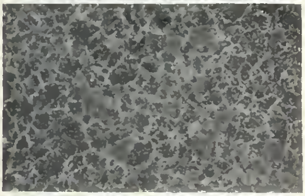

3.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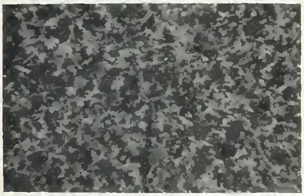
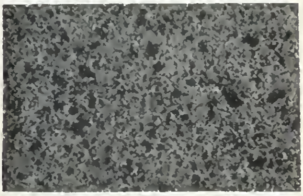
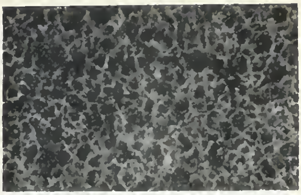
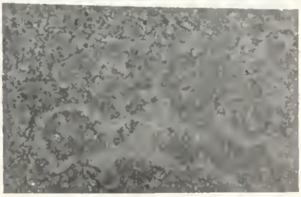
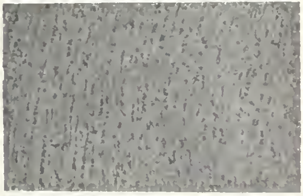
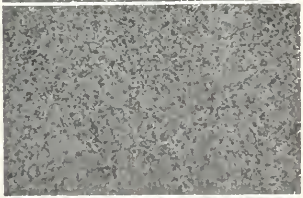

7.


9. 745°


11. 820°


2.


4.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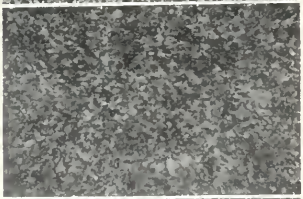
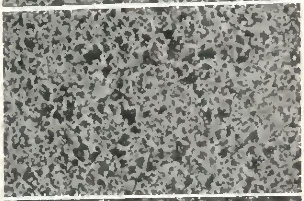

8. 735°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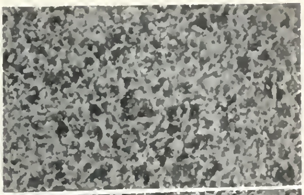
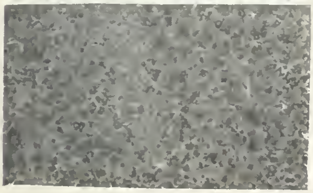
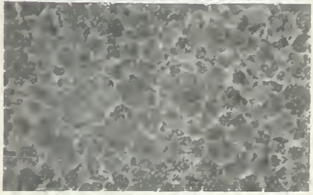

12.

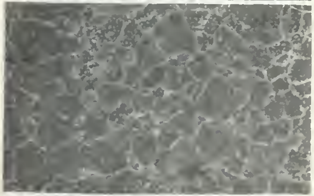
Reheat to Ae_1 — Furnace cooled

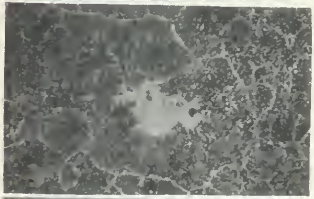
PLATE XII.
PROC. AM. SOC. TEST. MATS.
VOLUME VII.
CAMPBELL ON HEAT TREATMENT OF STEEL.

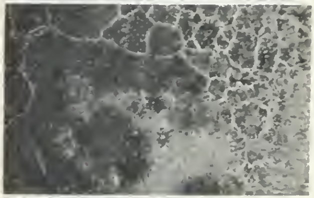
Cooled in air

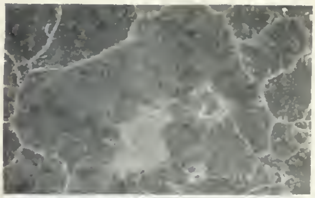

13. 900°

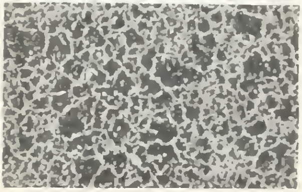

15. 1030°


17. 1150°


19. 1270°


21. 1270°


23. 1390°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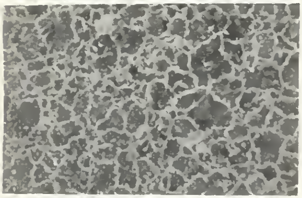
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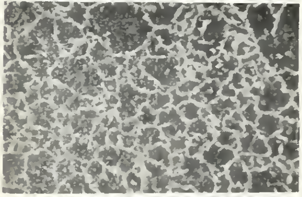
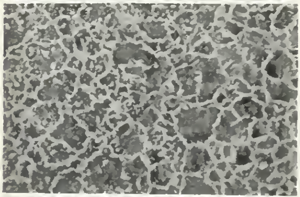

18.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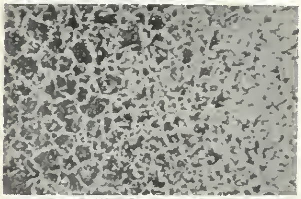
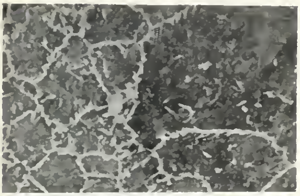
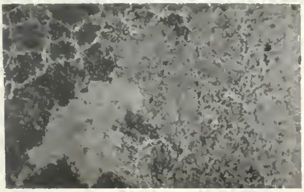
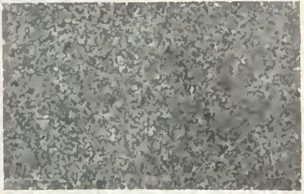

22.

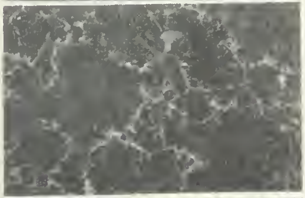

24.

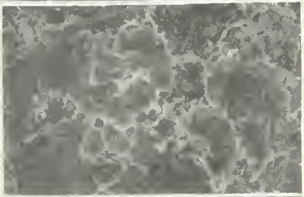
Furnace cooled

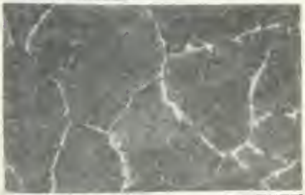
Cooled in air

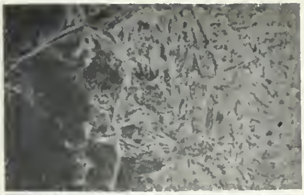

25. 1390°


27. As rolled.

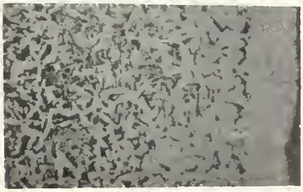

29. 1050°


31. 1165°


33. 1300°


35. 1300°

Furnace cooled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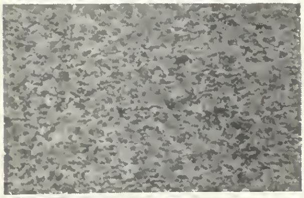
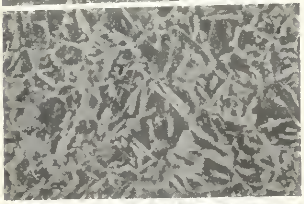
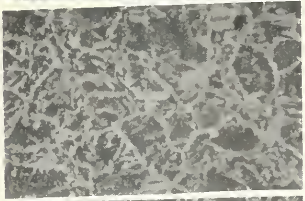
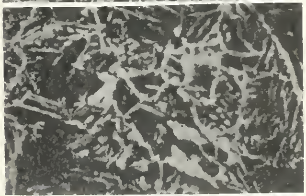

28.


30


32.


34.

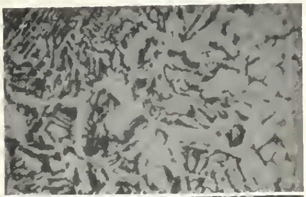

36.

PLATE XIV.
PROC. AM. SOC. TEST. MATS.
VOLUME VII.
HANCOCK ON TESTS OF STAYBOLTS.

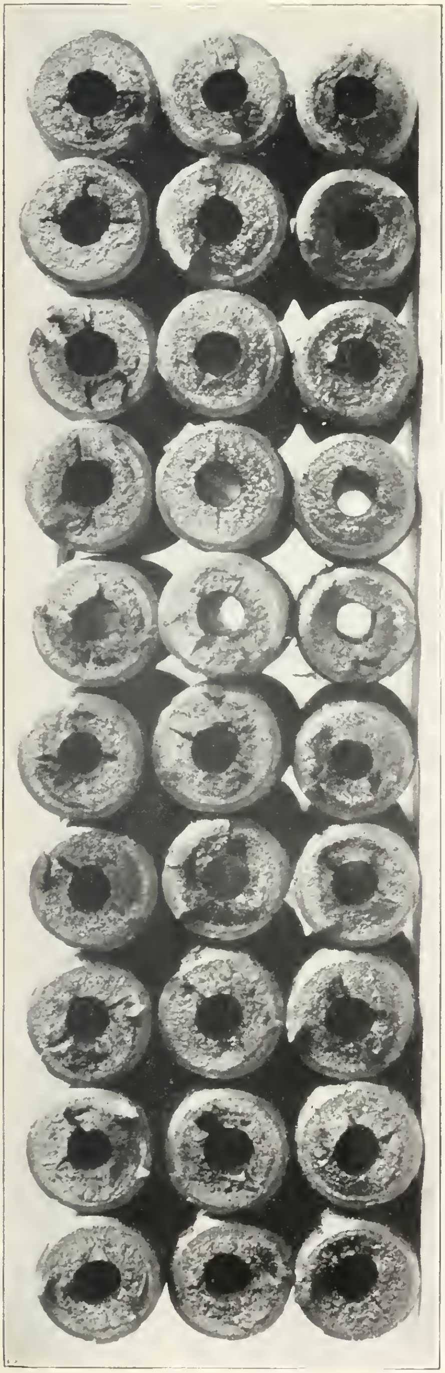


FIG. 3.—Fractured ends of threaded bolts.

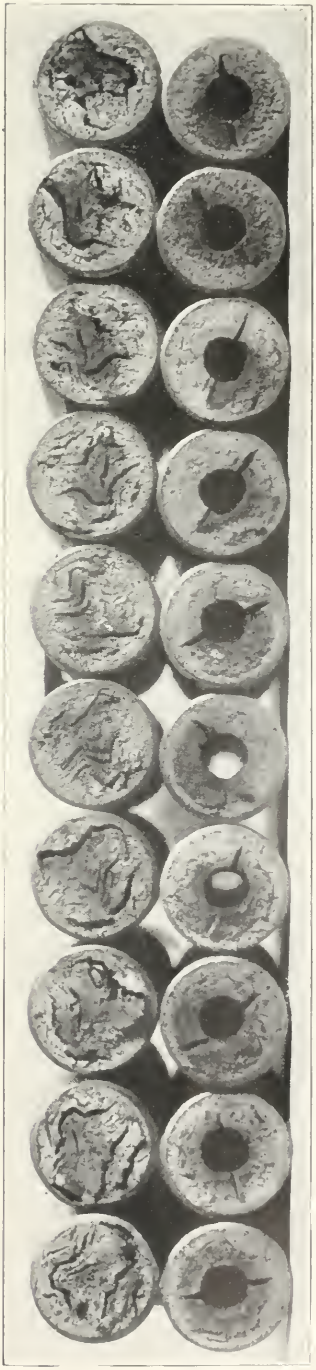


FIG. 4.—Fractured ends of unthreaded bolts.

PLATE XV.
PROC. AM. SOC. TEST. MATS.,
VOL. VII.
MCKIBBEN ON TESTS OF STEEL ANGLES

TABLE II.—SUMMARY OF TENSION TESTS OF STEEL ANGLES, 1906 AND 1907.

1906 TESTS:

Type	No. of specimen.	Nominal dimensions	Areas in square inches					Total breaking load in lbs.	Breaking loads in lbs. per square inch					Per cent of ultimate strength developed*				
			Actual gross.	Net right 13/16" holes.	Net right 1" holes	Least net Zigzag 13/16" holes	Least net Zigzag 1" holes		Actual gross area.	Net right section, 13/16" holes	Net right section, 1" holes	Least net Zigzag 13/16" holes	Least net Zigzag 1" holes	Actual gross area.	Net right section 13/16" holes.	Net right section 1" holes.	Least net Zigzag 13/16" holes.	Least net Zigzag 1" holes.
A1	1	3½" × 3" × ⅜"	2.29	1.95	1.93	...		89,500	39,100	45,900	46,400	..		65.9	77.4	78.3	.	
	2		2.32	1.97	1.95			96,100	41,400	48,800	49,300	.		69.8	82.3	83.2	.	
	3		2.35	2.00	1.98	.		95,200	40,500	47,600	48,100			68.3	80.3	81.1	. .	.
	Mean		2.32	1.97	1.95	.	.	93,600	40,300	47,400	47,900			68.0	80.0	80.9	.	.
A2	4	3½" × 3" × ⅜"	2.28	1.94	1.92	1.67	1.63	84,600	37,100	43,600	44,000	50,600	51,900	62.5	73.0	74.3	85.4	87.6
	5		2.31	1.97	1.94	1.69	1.64	88,600	38,300	45,000	45,600	52,400	54,000	64.5	76.0	77.0	88.4	91.1
	6		2.27	1.93	1.91	1.66	1.61	91,200	40,200	47,200	47,700	54,900	56,600	67.8	79.6	80.5	92.7	95.5
	Mean		2.29	1.95	1.92	1.67	1.63	88,100	38,500	45,300	45,800	52,600	54,200	64.9	76.4	77.3	88.8	91.4
B1	7	4" × 3" × ⅜"	2.43	2.10	2.07	.	.	85,000	35,000	40,500	41,100	.	..	64.8	75.0	76.1		
	8		2.42	2.09	2.06	. . .		84,000	34,700	40,200	40,800	. . . .	.	64.2	74.6	75.6	. .	.
	9		2.50	2.15	2.13	. . .	.	85,600	34,200	39,800	40,200			63.3	73.7	74.5	. .	.
	Mean		2.45	2.11	2.09	.		84,900	34,600	40,200	40,700	. .	.	64.1	74.4	75.4	. .	.
B2	10	4" × 3" × ⅜"	2.42	2.09	2.06	1.82	1.76	83,500	34,500	39,900	40,500	45,900	47,400	63.9	73.0	75.0	85.0	87.8
	11		2.43	2.09	2.07	1.81	1.76	85,100	35,000	40,700	41,100	47,000	48,400	64.8	75.4	76.1	87.1	89.7
	12		2.45	2.11	2.08	1.86	1.81	84,100	34,300	39,900	40,400	45,200	46,500	63.5	73.9	74.8	83.7	86.1
	Mean		2.43	2.10	2.07	1.83	1.78	84,200	34,600	40,200	40,700	46,000	47,400	64.1	74.4	75.3	85.3	87.9
B3	13	4" × 3" × ⅜"	2.40	2.07	2.04	. .	.	88,600	36,900	42,500	43,400	.	. .	68.3	79.3	80.3		
	14		2.42	2.09	2.06	. .	.	90,400	37,300	43,200	43,800	.	. .	69.0	80.0	81.1	.	.
	15		2.41	2.07	2.05	. . . .	. .	91,000	37,800	44,000	44,400	. . .	. . .	70.0	81.5	[illegible]		
	Mean		2.41	2.08	2.05	. . .	. .	90,000	37,300	43,300	43,900	.. ...	.. ..	69.1	80.3	81.2	.	.
C1	16	6" × 4" × ⅜"	3.53	3.17	3.15	3.11	3.06	131,000	37,100	41,300	41,600	42,100	42,800	71.9	80.0	80.7	81.8	[illegible]
	17		3.54	3.18	3.16	3.12	3.07	125,700	35,500	39,500	39,700	40,300	40,900	68.8	76.0	76.9	78.1	[illegible]
	18		3.50	3.14	3.12	3.07	3.03	128,200	36,600	40,800	41,100	41,800	42,300	70.9	79.1	79.7	81.0	82.0
	Mean		3.52	3.16	3.14	3.10	3.05	128,300	36,400	40,500	40,800	41,400	42,000	70.5	78.6	79.1	80.2	81.1
C2	19	6" × 4" × ⅜"	3.50	3.20	3.17	2.90	2.83	131,500	37,600	41,100	41,500	45,300	46,500	72.0	79.7	[illegible]	87.8	90.1
	20		3.50	3.19	3.17	2.89	2.82	130,200	37,200	40,800	41,100	45,000	46,200	72.1	79.1	[illegible]	[illegible]	89.5
	21		3.50	3.19	3.17	2.89	2.82	131,900	37,700	41,300	41,600	45,600	46,800	73.0	80.1	[illegible]	88.4	90.7
	Mean		3.50	3.19	3.17	2.89	2.82	131,200	37,500	41,100	41,400	45,300	46,500	72.7	79.6	[illegible]	[illegible]	[illegible]
D1	22	2-3" × 3" × 5/16"	3.44	2.88	2.84	. . ..	.	134,100	39,000	46,600	47,200	..		64.0	76.4	[illegible]		
	23		3.43	2.87	2.83	. . .		136,500	39,800	47,600	48,200	. .	.	65.2	78.1	[illegible]		
	24		3.50	2.92	2.88			[illegible]	39,800	[illegible]	48,300	.		[illegible]	78.2			
	Mean		3.46	2.89	2.85		.	136,600	39,500	47,300	47,900	. ..		64.8	77.6	.		
D2	25	2-3" × 3" × 5/16"	3.43	2.87	2.83	2.48	2.41	137,800	40,100	48,000	48,700	55,600	57,200	65.7	78.7	[illegible]	[illegible]	[illegible]
	26		3.43	2.87	2.83	2.47	2.40	140,400	40,900	48,900	49,600	56,800	58,500	67.0	80.2	[illegible]	[illegible]	[illegible]
	27		3.42	2.86	2.82	2.46	2.39	138,800	40,600	48,500	49,200	56,400	58,100	66.6	79.5	[illegible]	[illegible]	[illegible]
	Mean		3.43	2.87	2.83	2.47	2.40	139,000	40,500	48,500	49,200	56,300	57,900	66.4	79.5	[illegible]	[illegible]	[illegible]
	1907 TESTS																	
A3	28	3½" × 3" × ⅜"	2.21	1.91	1.89	1.96	1.92	94,400	42,100	49,400	49,900	48,100	49,200	72.0	85.5	[illegible]	[illegible]	87.1
	29		2.26	1.93	1.91	1.98	1.94	96,900	42,900	50,200	50,700	48,900	49,900	71.3	86.0	[illegible]	[illegible]	[illegible]
	30		2.25	1.92	1.90	1.98	1.93	98,200	43,600	51,100	51,700	49,600	50,900	75.5	88.5	[illegible]	[illegible]	88.0
	Mean		2.25	1.92	1.90	1.97	1.93	96,500	42,900	50,200	50,800	48,900	50,000	74.2	87.0	[illegible]	84.0	86.5
A4	31	3½" × 3" × ½"	2.27	1.93	1.91	1.99	1.94	99,600	43,900	51,600	52,100	50,000	51,400	76.0	89.3	[illegible]	[illegible]	89.0
	32		2.23	1.91	1.89	1.98	1.91	97,400	[illegible]	51,000	51,500	49,000	51,000	75.5	88.3	[illegible]	[illegible]	[illegible]
	33		2.25	1.92	1.90	1.97	1.93	99,200	44,100	51,700	52,200	50,400	51,400	76.3	89.5	[illegible]	[illegible]	89.0
	Mean		2.25	1.92	1.90	1.97	1.93	98,700	43,900	51,400	51,900	50,000	[illegible]	75.9	89.0	[illegible]	[illegible]	[illegible]
A5	34	3½" × 3" × ⅜"	2.27	1.93	1.91	1.98	1.94	97,600	43,000	50,600	51,100	49,300	50,300	76.1	89.6	[illegible]	[illegible]	89.1
	35		2.28	1.95	1.93	2.00	1.96	98,500	43,200	50,500	51,000	49,300	50,300	76.5	89.5	[illegible]	[illegible]	89.1
	36		2.26	1.92	1.90	1.98	1.94	97,900	43,300	51,000	51,500	49,500	50,500	76.6	90.3	[illegible]	[illegible]	89.4
	Mean		2.27	1.93	1.91	1.99	1.95	98,000	43,200	50,700	51,200	49,100	50,400	76.4	89.8	[illegible]	[illegible]	89.2
B4	37	4" [illegible]	2.41	2.08	2.06	2.10	2.06	100,400	41,700	48,300	48,800	47,900	48,800	77.0	90.1	[illegible]	[illegible]	[illegible]
	38		2.40	2.06	2.04	2.08	2.04	98,300	41,000	47,700	48,200	47,200	48,200	76.5	89.0	[illegible]	[illegible]	[illegible]
	39		2.43	2.10	2.08	2.12	2.07	101,400	41,700	48,300	48,800	47,800	49,000	77.0	90.1	[illegible]	[illegible]	[illegible]
	Mean		2.41	2.08	2.06	2.10	2.06	100,000	41,500	48,100	48,600	47,600	48,700	[illegible]	89.7	[illegible]	[illegible]	[illegible]
B5	40	4" [illegible]	2.39	2.06	2.04	2.09	2.01	100,500	42,000	48,800	49,300	48,100	49,900	78.4	91.0	[illegible]	[illegible]	[illegible]
	41		2.41	2.08	2.06	2.11	2.06	103,500	42,900	49,800	50,200	49,000	50,200	80.1	92.0	[illegible]	[illegible]	[illegible]
	42		2.48	2.11	2.12	2.16	2.12	104,500	42,100	[illegible]	49,300	[illegible]	[illegible]	[illegible]	91.0	[illegible]	[illegible]	[illegible]
	Mean		2.43	2.09	2.07	2.12	2.07	102,800	[illegible]	[illegible]	49,600	48,500	[illegible]	79.0	91.0	[illegible]	[illegible]	[illegible]
B6	43	4" [illegible] × ⅜"	2.39	2.06	2.04	2.03	1.99	100,600	42,000	[illegible]	49,300	49,500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B7	44		2.44	2.10	2.09	2.03	1.98	[illegible]	42,400	[illegible]	[illegible]	51,000	52,300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B8	45		2.40	2.00	2.01	1.95	1.90	101,800	42,400	[illegible]	49,000	52,200	53,500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C3	46	6" × 4" × ⅜"	3.60	3.24	3.22	. . . .		154,600	42,900	47,700	48,000			[illegible]	[illegible]			
	47		3.60	3.20	3.18	. . ..		[illegible]	[illegible]	[illegible]	[illegible]			71.0	78.8			
	48		3.58	3.22	3.20	. . . .		[illegible]	42,800	[illegible]	47,900			71.8	[illegible]			
	Mean		3.59	3.22	3.20	. . .		152,800	42,700	[illegible]	47,700		..	71.6	[illegible]			
C4	49	6" × 4" × ⅜"	3.58	3.21	3.18	3.31	3.26	150,600	[illegible]	[illegible]	47,300	45,500	46,200	71.0	78.6	[illegible]	[illegible]	[illegible]
	50		3.54	3.19	3.16	3.29	[illegible]	144,100	40,700	[illegible]	45,600	43,800	[illegible]	68.3	75.9	[illegible]	[illegible]	[illegible]
	51		3.54	3.19	3.17	3.29	[illegible]	[illegible]	[illegible]	[illegible]	48,000	46,300	46,800	72.1	80.0	[illegible]	[illegible]	[illegible]
	Mean		3.55	3.20	3.17	3.30	[illegible]	[illegible]	42,000	[illegible]	47,000	45,200	[illegible]	70.5	78.2	[illegible]	[illegible]	[illegible]
C5	52	6" × 4" × ⅜"	3.54	3.18	3.16	3.20	3.16	[illegible]	40,500	[illegible]	45,400	44,800	[illegible]	68.0	75.7	[illegible]	[illegible]	[illegible]
	53		3.53	3.18	3.16	3.20	[illegible]	[illegible]	[illegible]	46,500	46,800	[illegible]	[illegible]	[illegible]	78.0	[illegible]	[illegible]	[illegible]
	54		3.51	3.16	3.14	3.18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	46,000	[illegible]	70.1	77.7	[illegible]	[illegible]	[illegible]
	Mean		3.53	3.17	3.15	3.19	[illegible]	[illegible]	41,400	46,000	[illegible]	45,700	[illegible]	69.4	77.1	[illegible]	[illegible]	77.8
D3	55	2-3" × 3" × 5/16"	3.43	2.88	2.84	.		[illegible]	40,800	[illegible]	49,300			68.1	81.2	[illegible]		
	56		3.39	2.83	2.79			140,700	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			
	57		3.39	2.83	2.79			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			
	Mean		3.40	2.85	2.81			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	82.3			
D4	58	2-3" × 3" × 5/16"	3.38	2.83	2.80	2.87	2.80	[illegible]	[illegible]	[illegible]	48,400	[illegible]	[illegible]	[illegible]	81.5	[illegible]	[illegible]	[illegible]
	59		3.34	2.79	2.76	2.84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	82.1	[illegible]	[illegible]	[illegible]
	60		3.37	2.82	2.78	2.87	2.78	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Mean		3.36	2.81	2.78	2.86	[illegible]	[illegible]	[illegible]	[illegible]	48,000	[illegible]	[illegible]	67.1	[illegible]	[illegible]	[illegible]	[illegible]

*Figures of five preceding columns compared with results of test bars

PLATE XVI.
PROC. AM. SOC. TEST. MATS.
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TIEMANN ON THE STRENGTH OF WOOD.

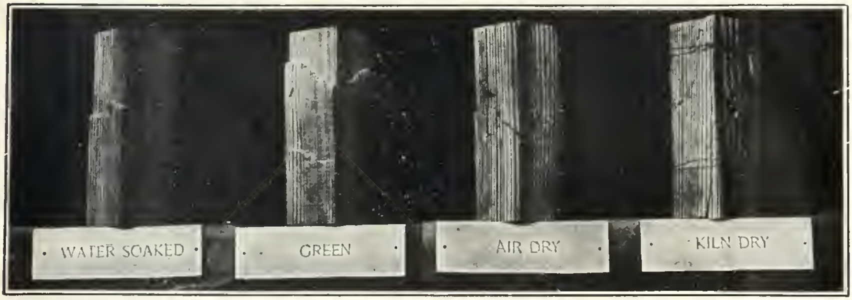


FIG. 1.—Longleaf Pine.

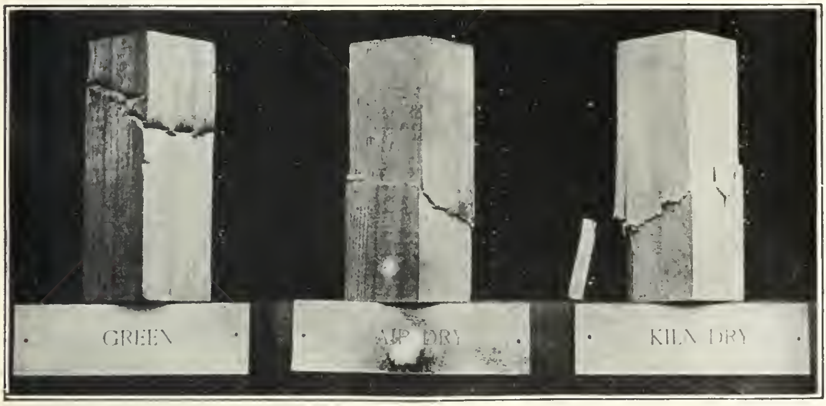


FIG. 2.—Spruce.

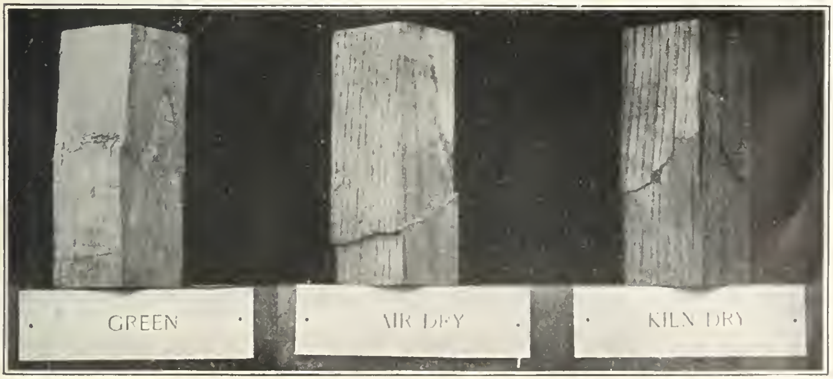
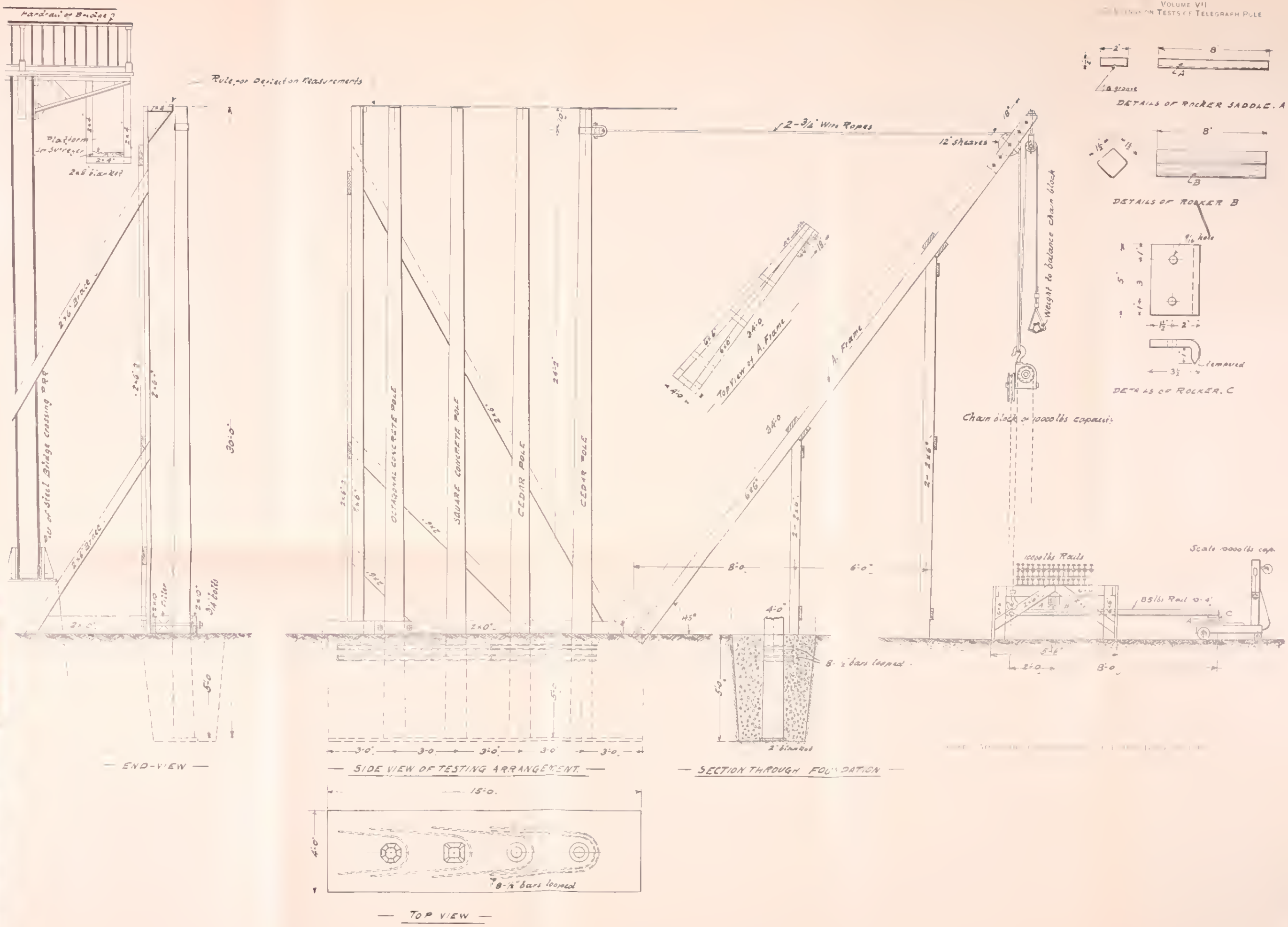


FIG. 3.—Chestnut.

Manner of Failure in Compression Tests of Wood in Different Moisture Conditions.

Tieman, Bul. 70, *Forest Service*, U. S. Dept. Agriculture.

PLATE XVII
PROC. AM. SOC. TEST. MATS.
VOLUME VII
[illegible] ON TESTS OF TELEGRAPH POLE



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